

Global Integrated Sachs-Wolfe Significance: An Exercise in Method & Hubris

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It Seemed Like a Good Idea at the Time...

Date: Fri, 5 May 2006 17:54:32 -0400 (EDT)
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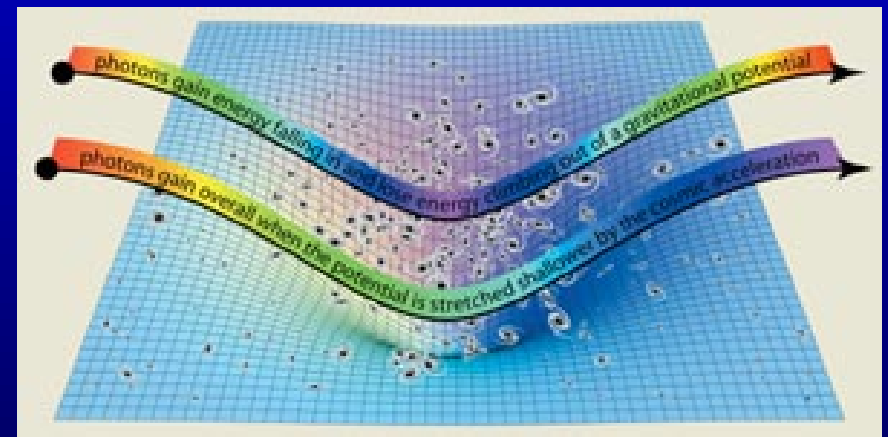
Hey Albert...

As for the conference, I'm not entirely certain what I'm going to talk about. I'm toying with the idea of doing a global measurement of the ISW using 2MASS, SDSS, and FIRST/NVSS using the Teragrid. Given the fact that I was able to do the LRG stuff in less than 24 hours, I think I can do it all by the end of next week.

-Ryan

ISW in 2 Minutes

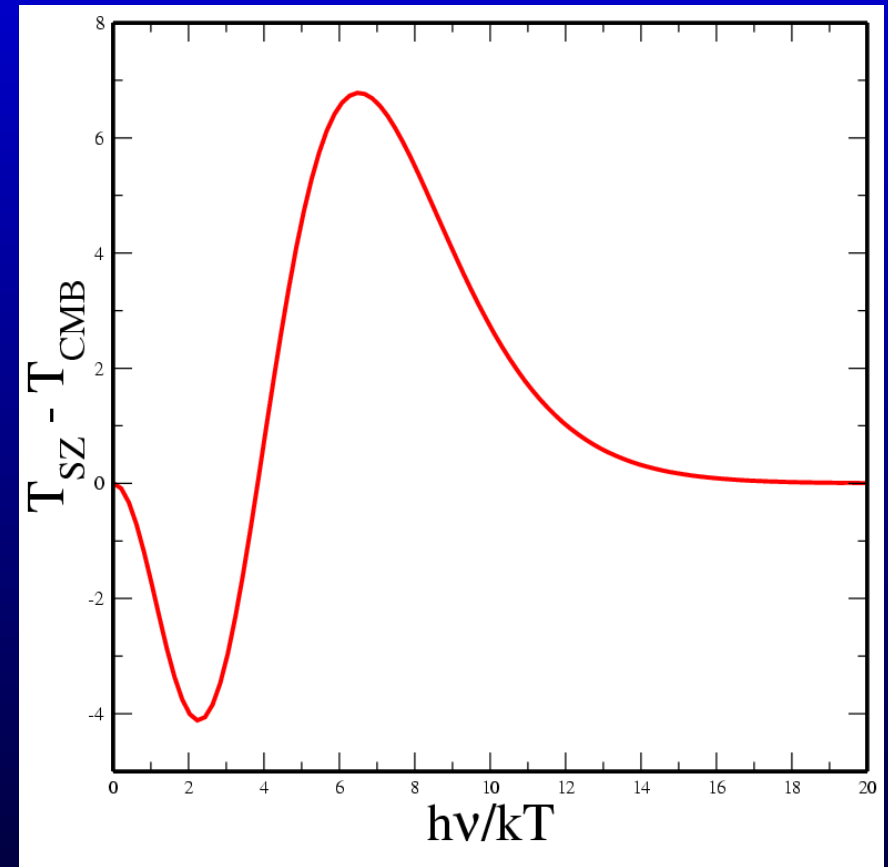
- After matter-radiation equality, dark matter falls into potential wells set up during inflation. For Λ CDM, universe expands faster than potentials grow
- CMB photons passing through potentials see net blue-shift in energy \Rightarrow **Integrated Sachs-Wolfe Effect**
- Increases CMB autocorrelation at small l and induces positive correlation with galaxies



PhysicsWeb

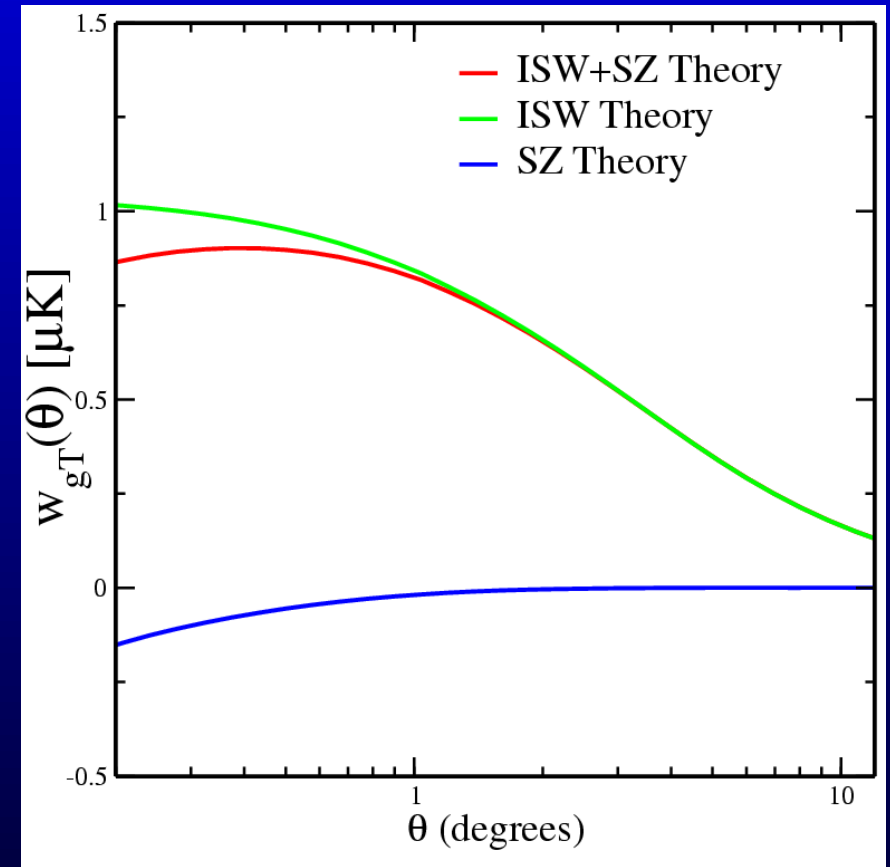
Thermal Sunyaev-Zel'dovich Effect

- Hot electron gas surrounds galaxy filaments and clusters
- CMB photons inverse Compton scatter off of electrons, shifting photons to higher energies
- CMB in Rayleigh-Jeans region of original spectrum gives observed temperature decrement \Rightarrow anti-correlation with foreground structure



Expected Signal

- Expect ISW to dominate on large angles, SZ to become important on smaller angles
- 2 free parameters in linear theory: galaxy bias ($\delta_{gal} = b_{gal}\delta_{DM}$) and electron gas-bias ($T_e b_P$). b_{gal} controls overall amplitude of the signal and $T_e b_P$ determines the relative importance of the SZ effect
- Very important to maximize sky coverage (cosmic variance) and keep Poisson noise low



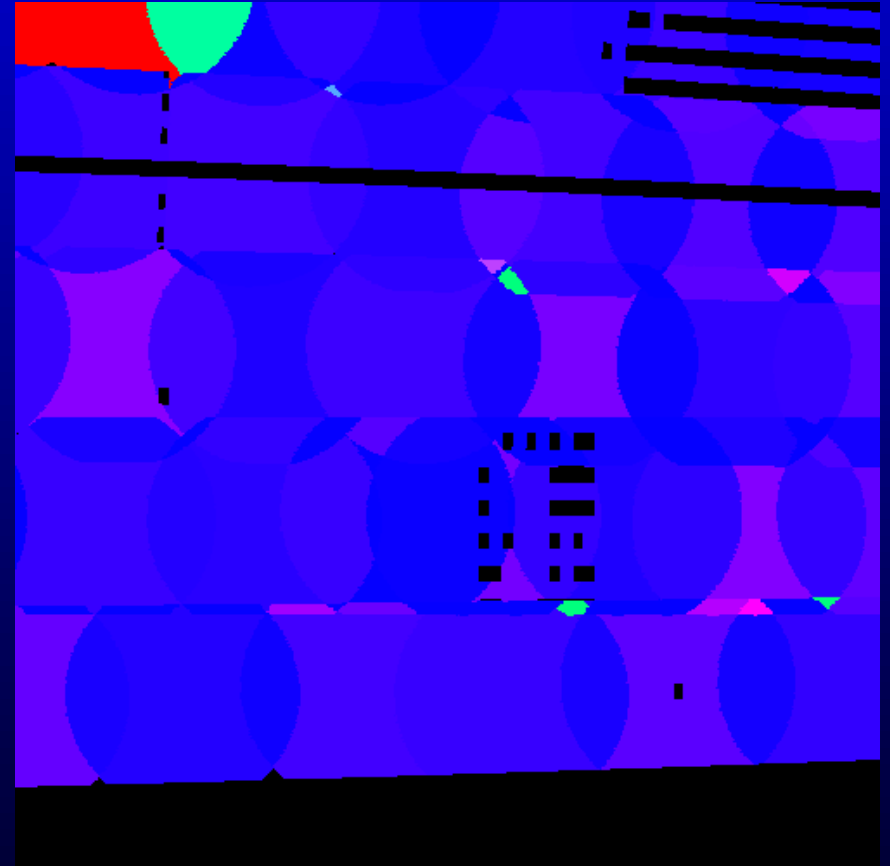
The Plan

- Collect footprints & galaxy data from 2MASS, SDSS, FIRST and NVSS
- 15 total maps covering $0 < z < 2.5$:
 - ★ 3 2MASS magnitude limited samples ($10.5 < k < 11.5$, $11.5 < k < 12.5$, $12.5 < k < 13.5$)
 - ★ 5 magnitude limited SDSS galaxy samples over $16 < r < 21$
 - ★ 3 SDSS LRG redshift slices
 - ★ NVSS radio galaxies
 - ★ 2 FIRST samples (star forming galaxies with flux < 10 mJy, AGNs with flux > 50 mJy)
 - ★ Photometric SDSS QSOs with $1 < z < 2.5$
- Cross-correlate with smoothed 3 year WMAP w channel map
- Generate global covariance matrix using 10,000 CMB realizations on Teragrid

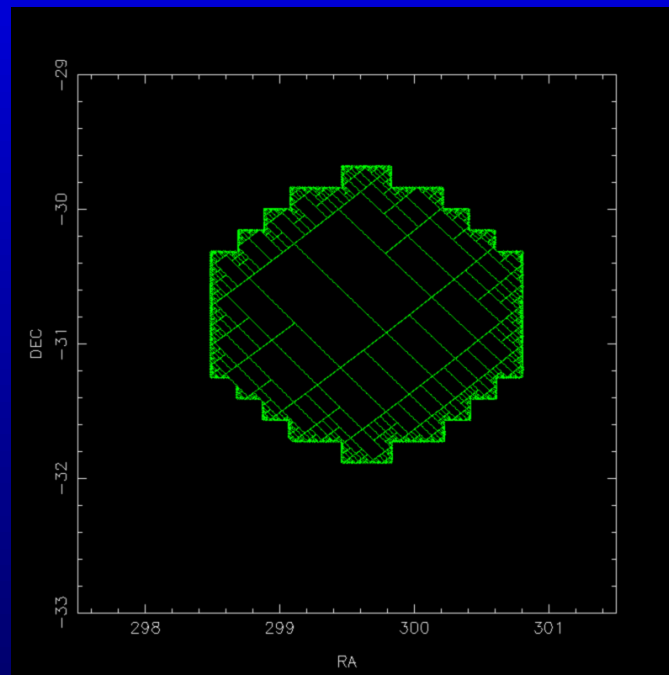
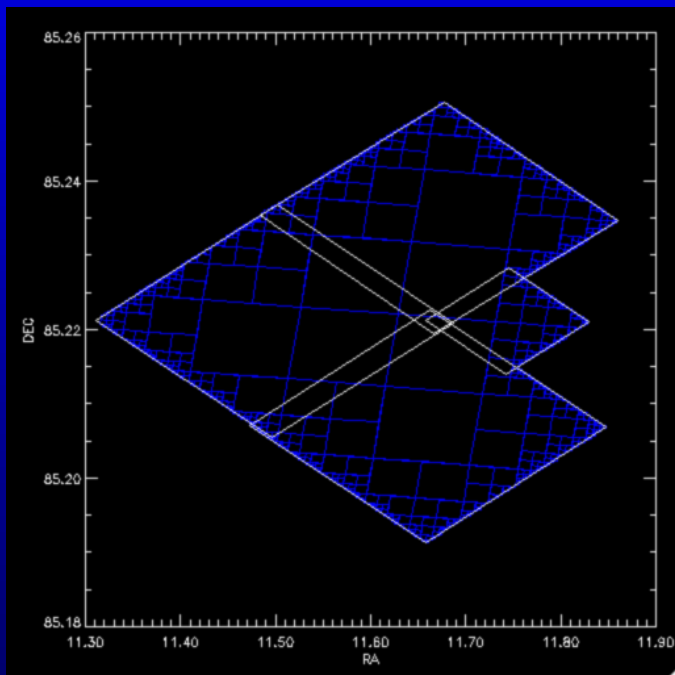
STOMP: Space and Time Ordered Mapping Package

<http://nvogre.phyast.pitt.edu/gestalt/>

- All cosmological statistics are measurements of spatial properties (area, angular distance, density)
- Describe complex geometries on the sphere and possibly spatial variations
- Find unions, intersections, and overlaps between large numbers of observations
- It has to be fast

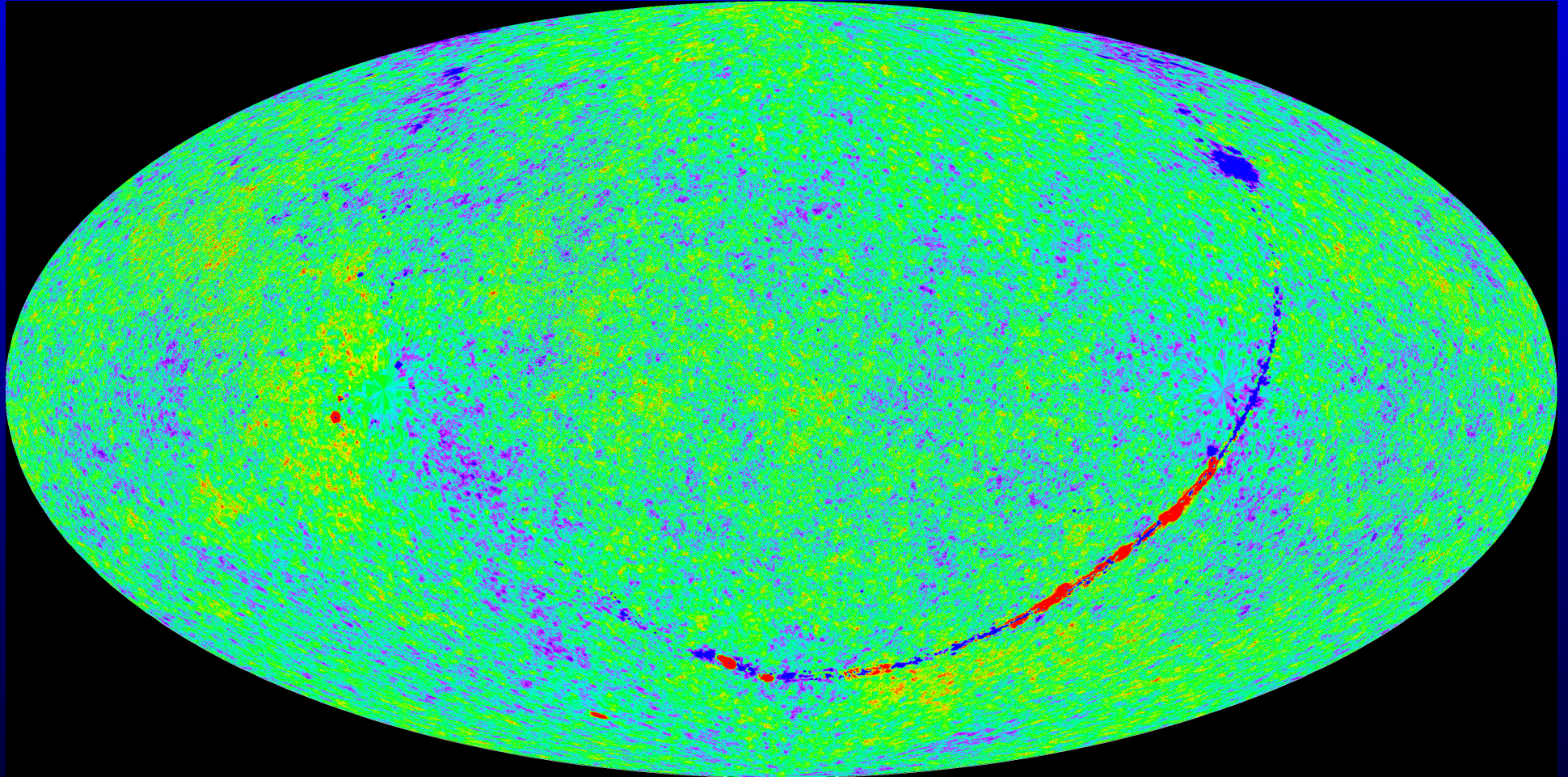


STOMP: Space and Time Ordered Mapping Package



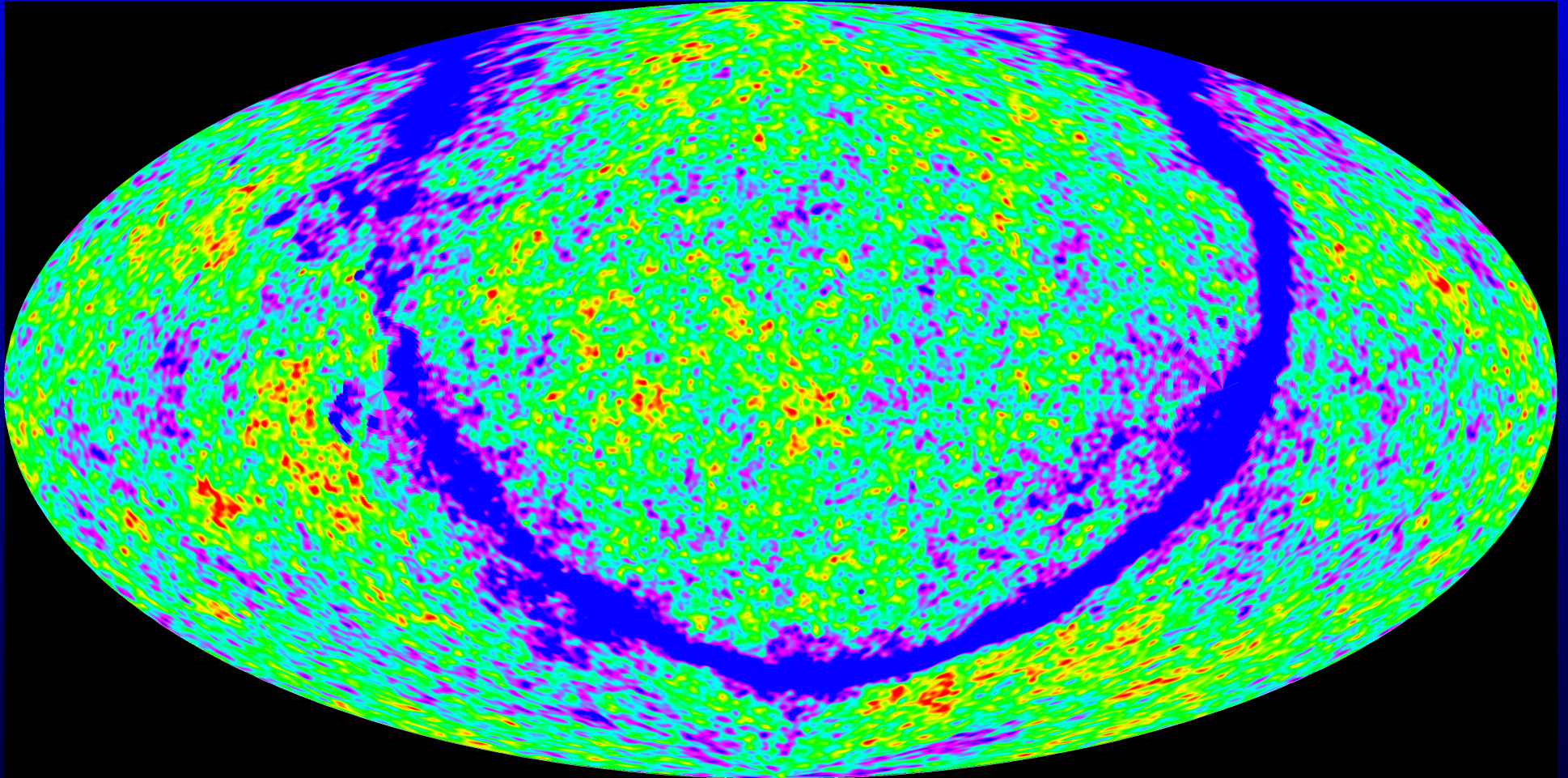
- Pixelize arbitrary survey footprints with 1'' resolution
- Hierarchical scheme: extremely rapid localization & efficient angular statistics.
- All footprints & analysis done with current STOMP code

CMB Side



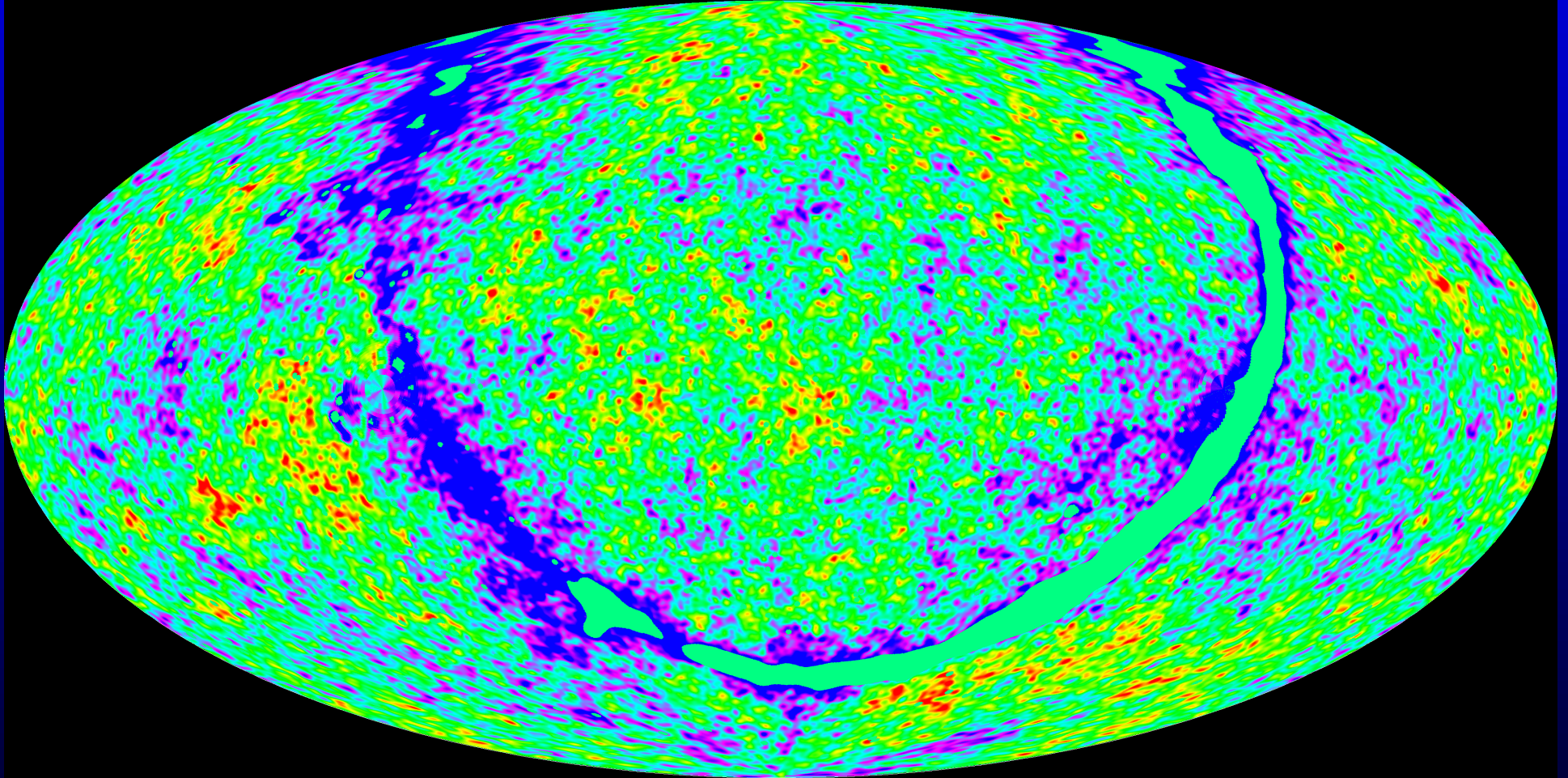
WMAP w channel

CMB Side

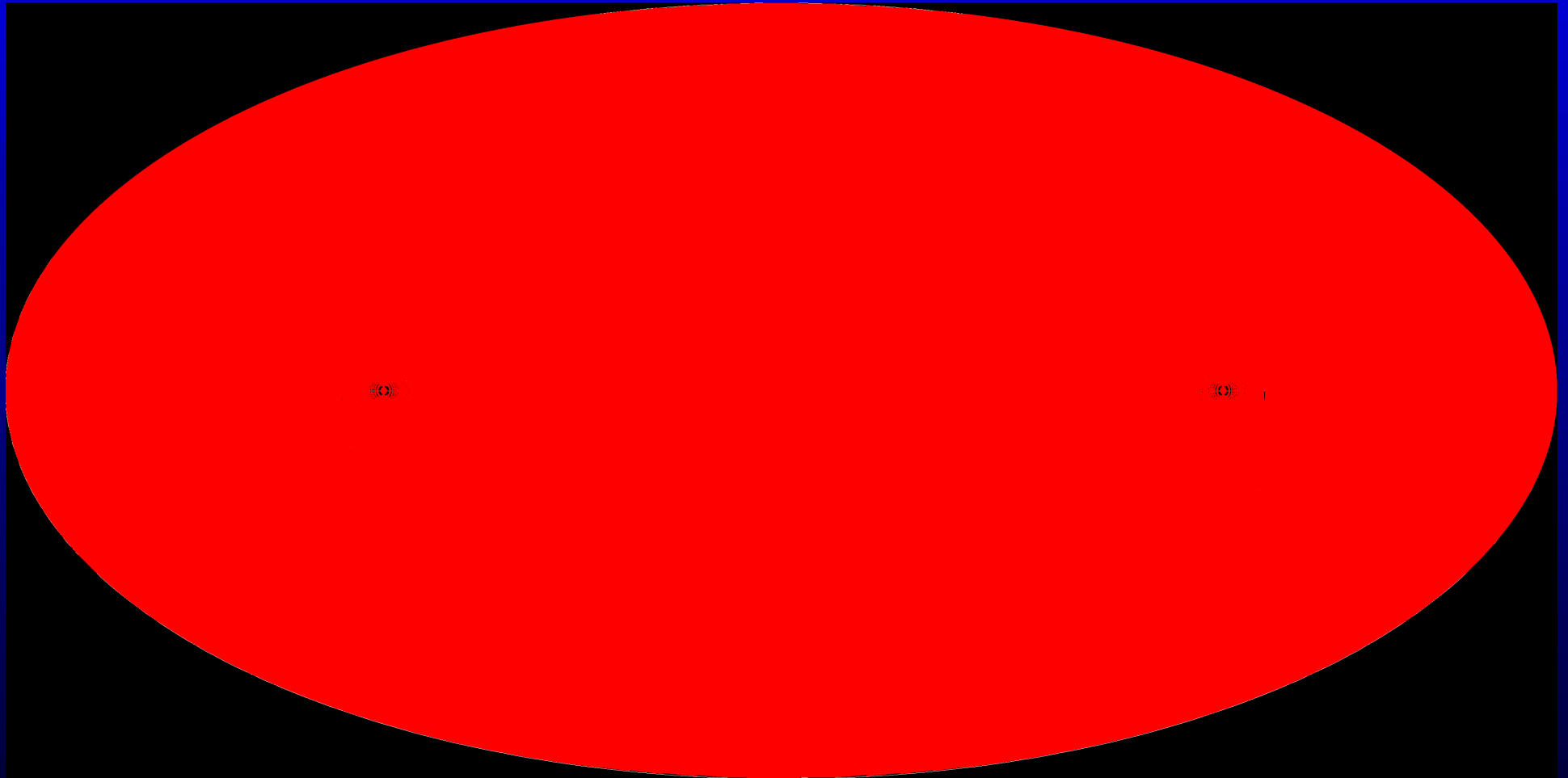


WMAP w channel – smoothed to 1°

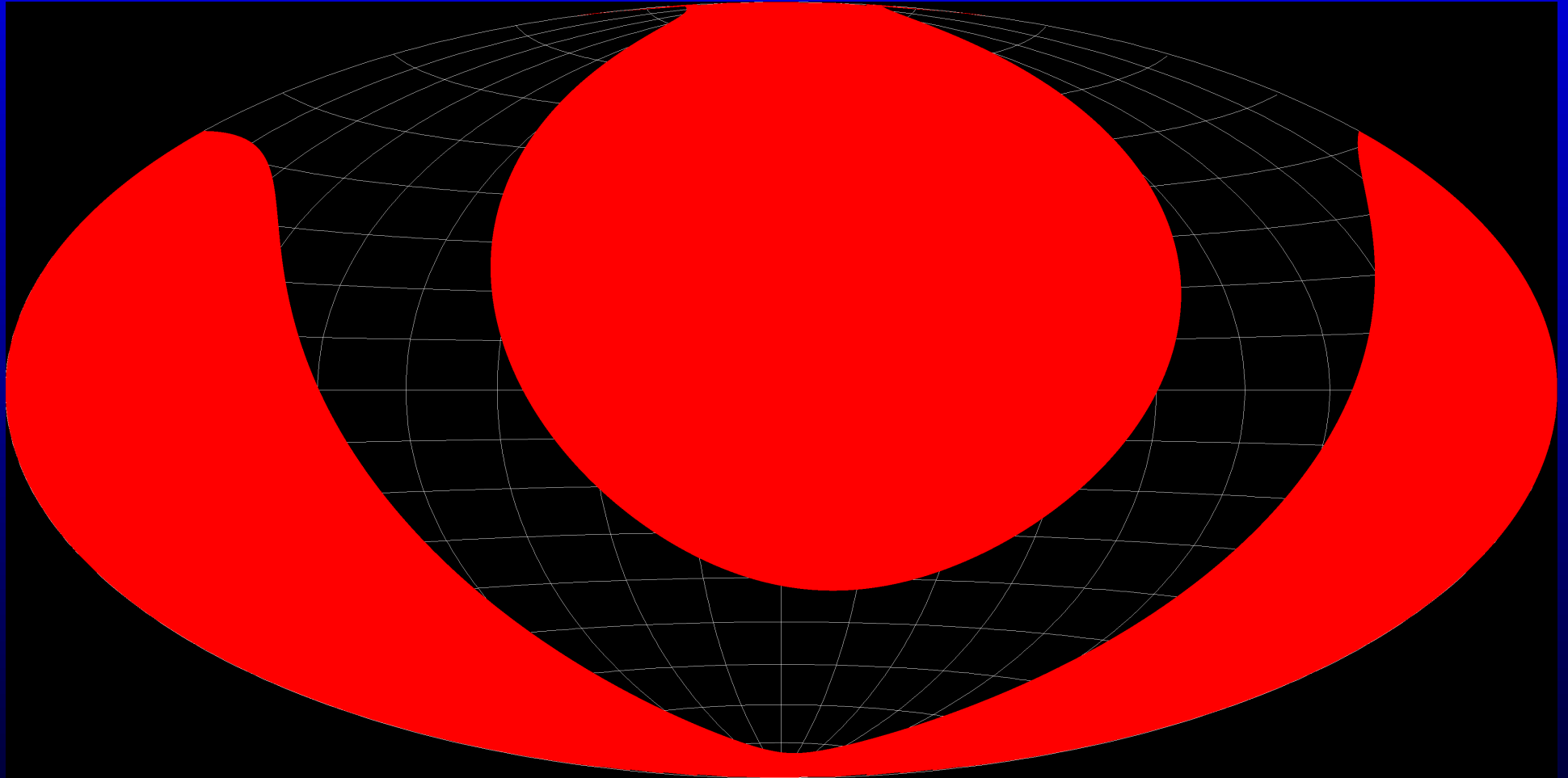
CMB Side



WMAP w channel – smoothed & masked (??)

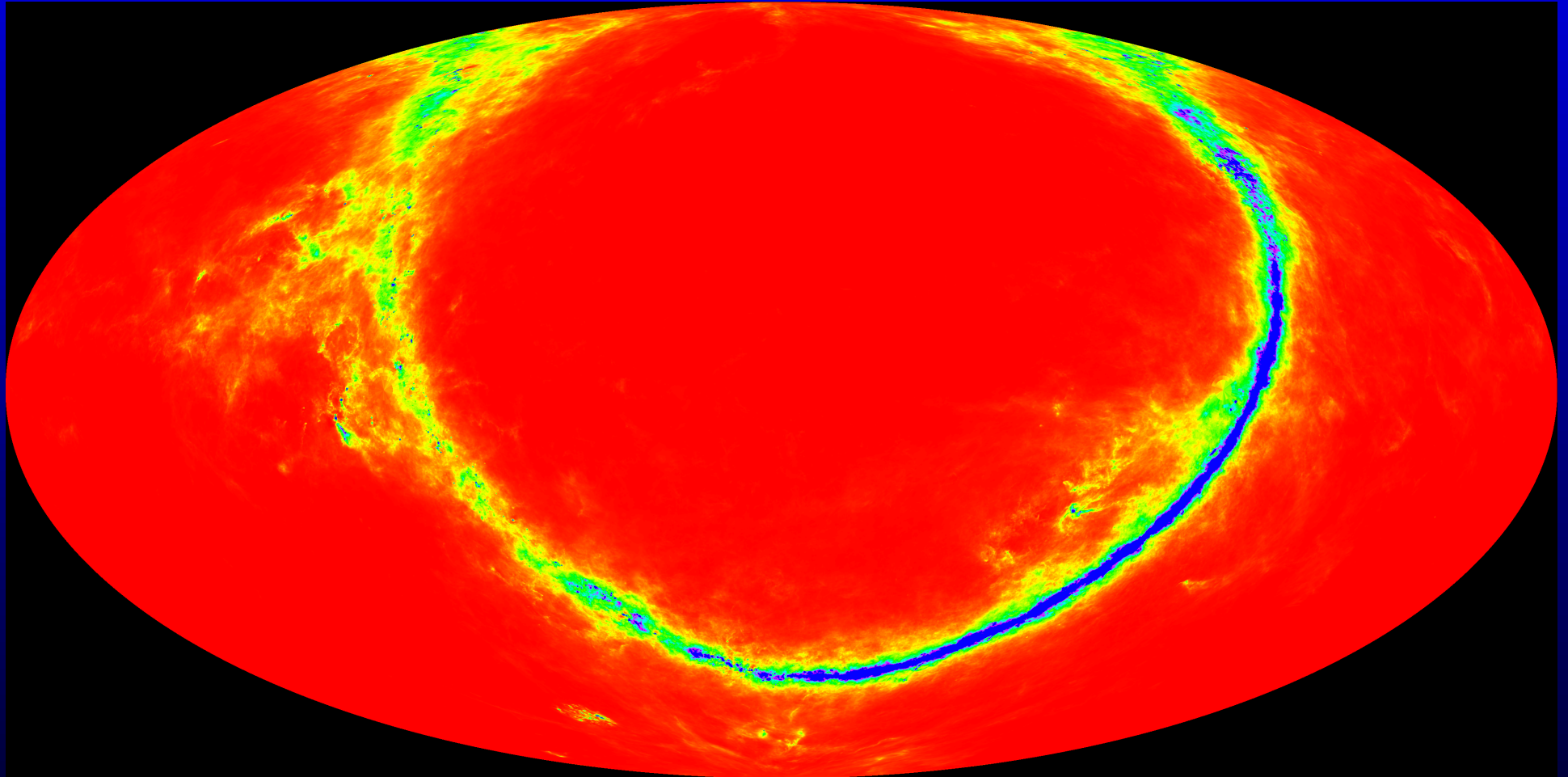
2MASS

2MASS

2MASS

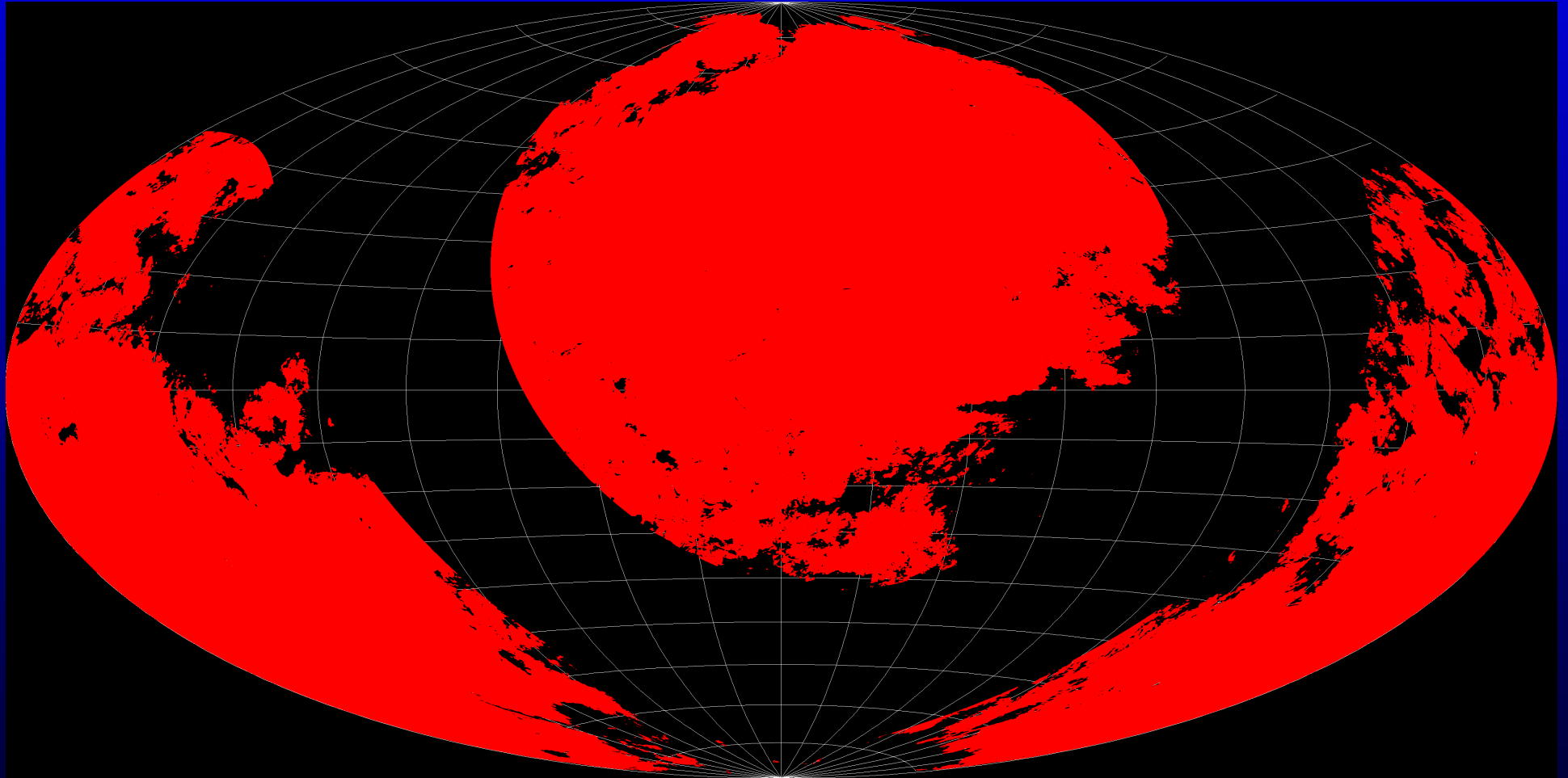
$$2\text{MASS} - |b| > 20$$

DIRBE



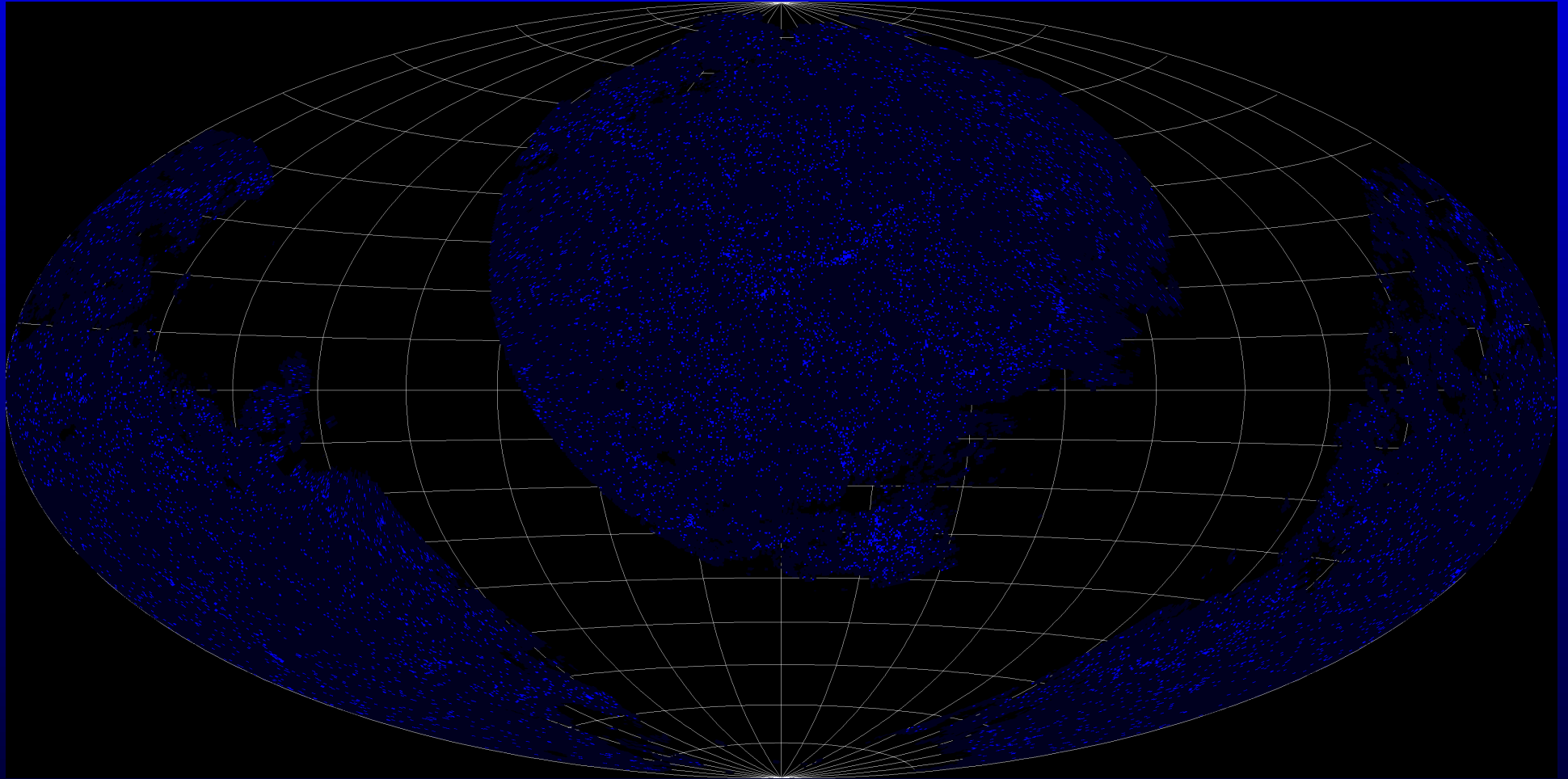
SFD $E(B-V)$ dust emission

2MASS



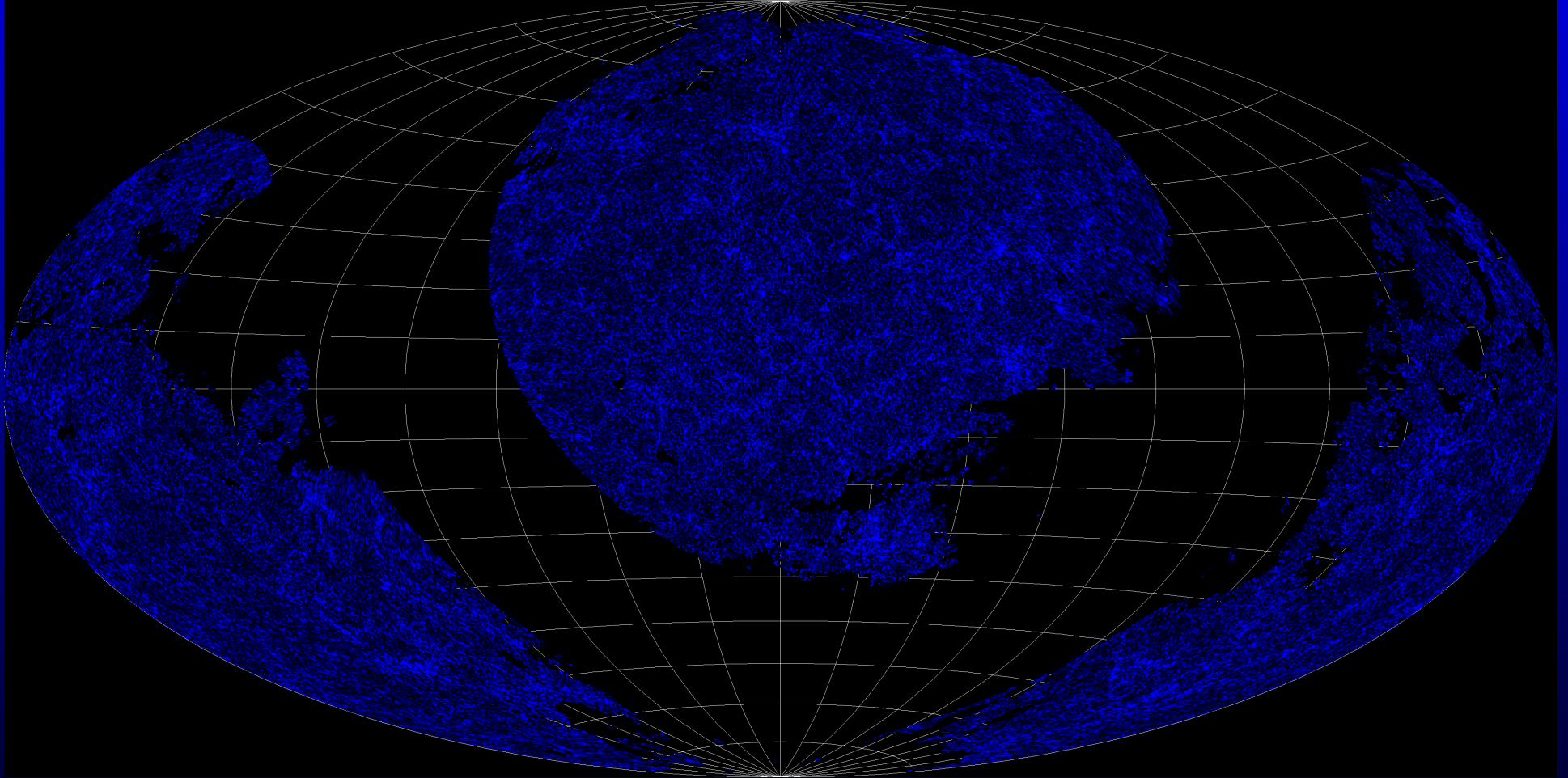
$$2MASS - |b| > 20, A_k < 0.03$$

2MASS



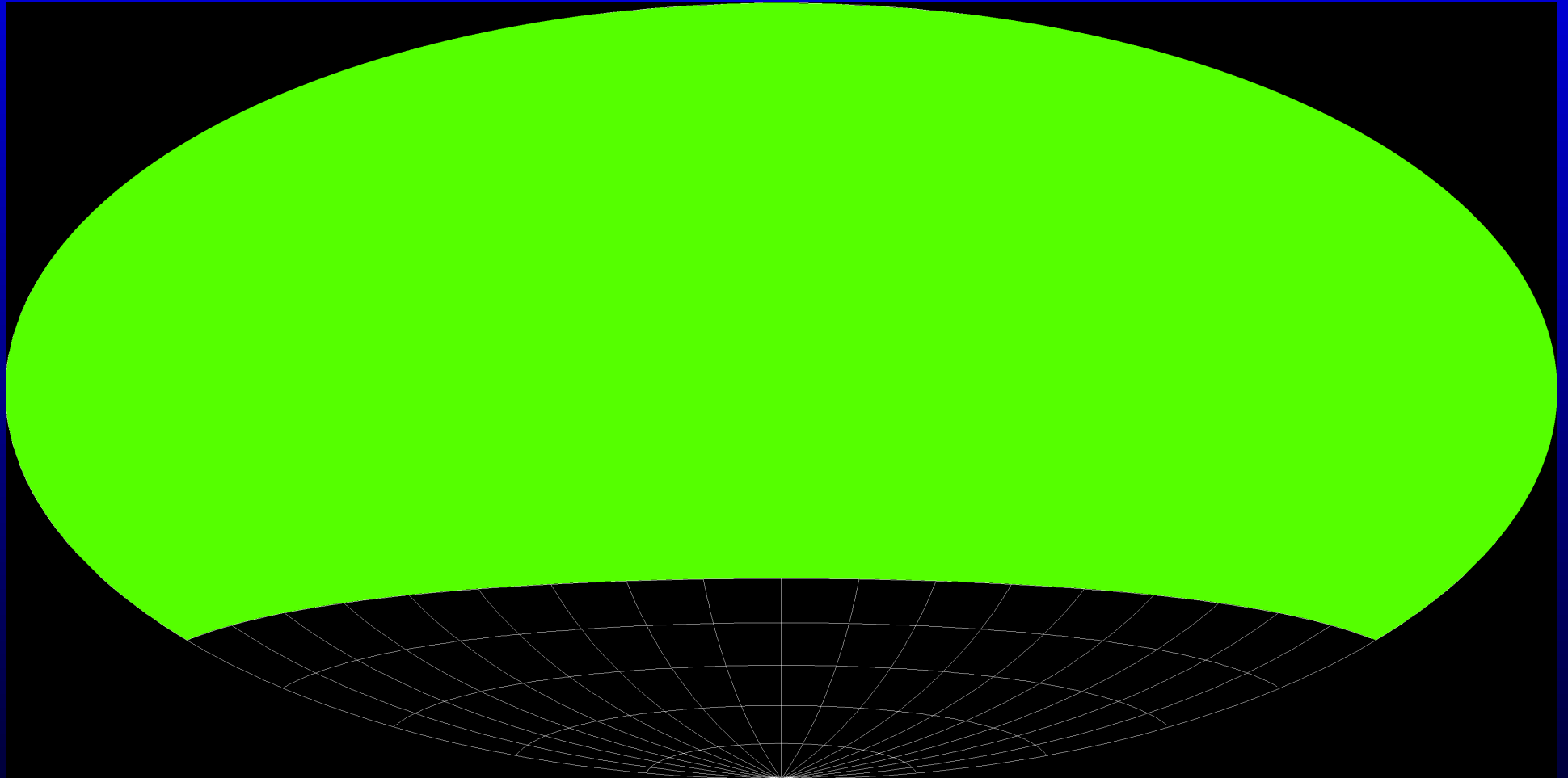
2MASS Over-Density – $10.5 < k < 11.5$, $z \sim 0.05$

2MASS

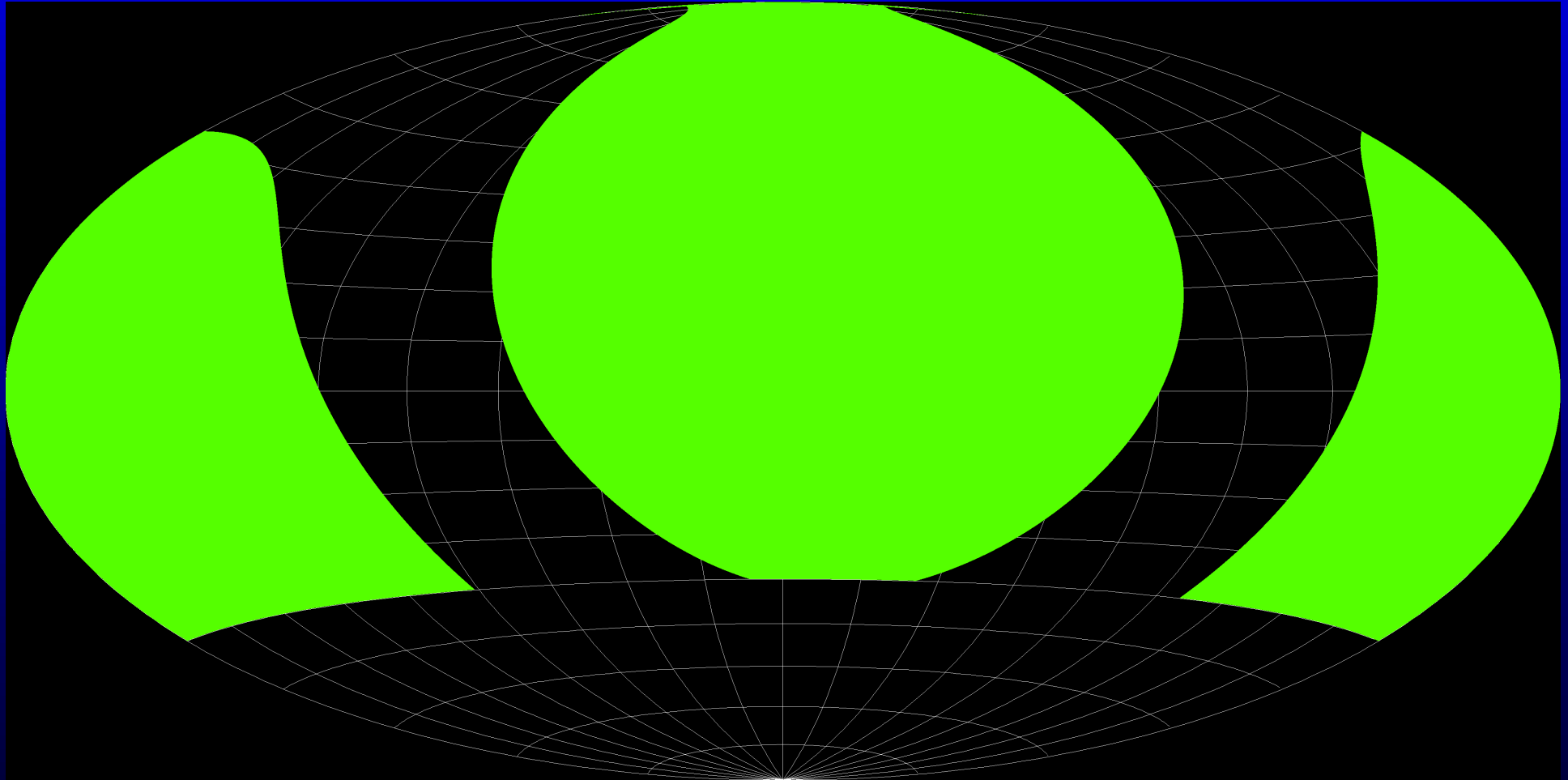


2MASS Over-Density – $12.5 < k < 13.5$, $z \sim 0.1$

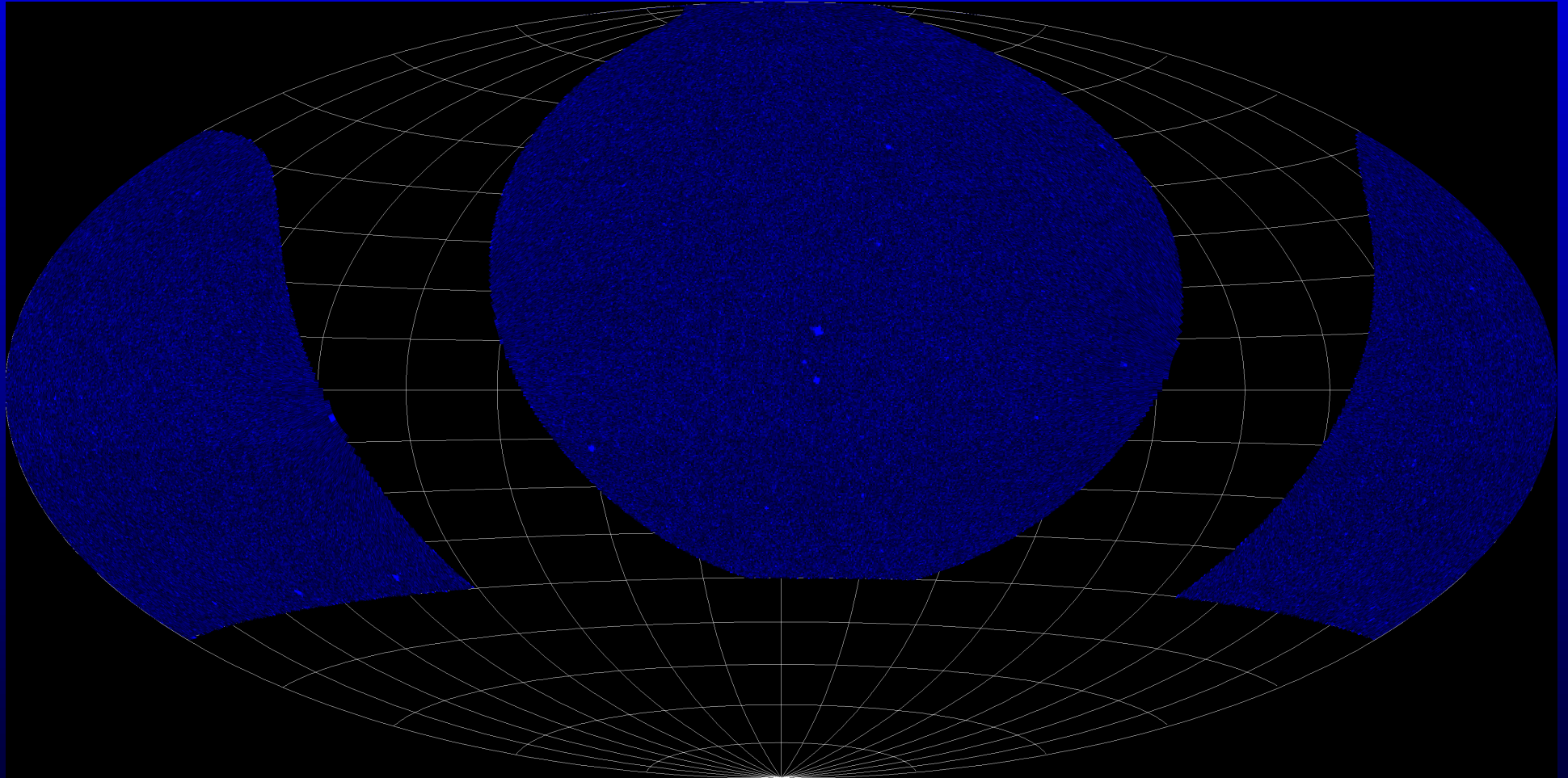
NVSS



NVSS

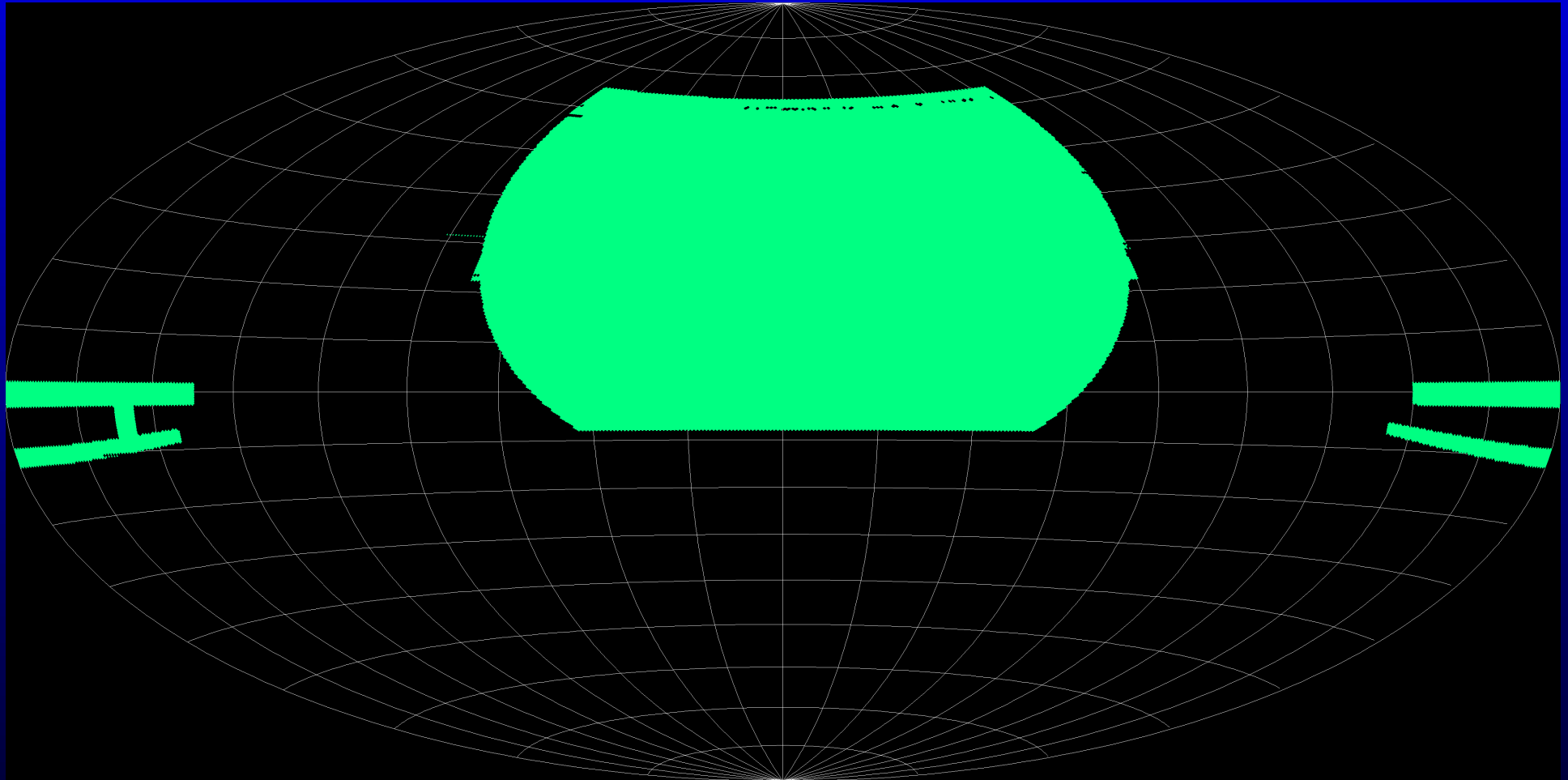
NVSS $\text{NVSS} - |b| > 20$

NVSS



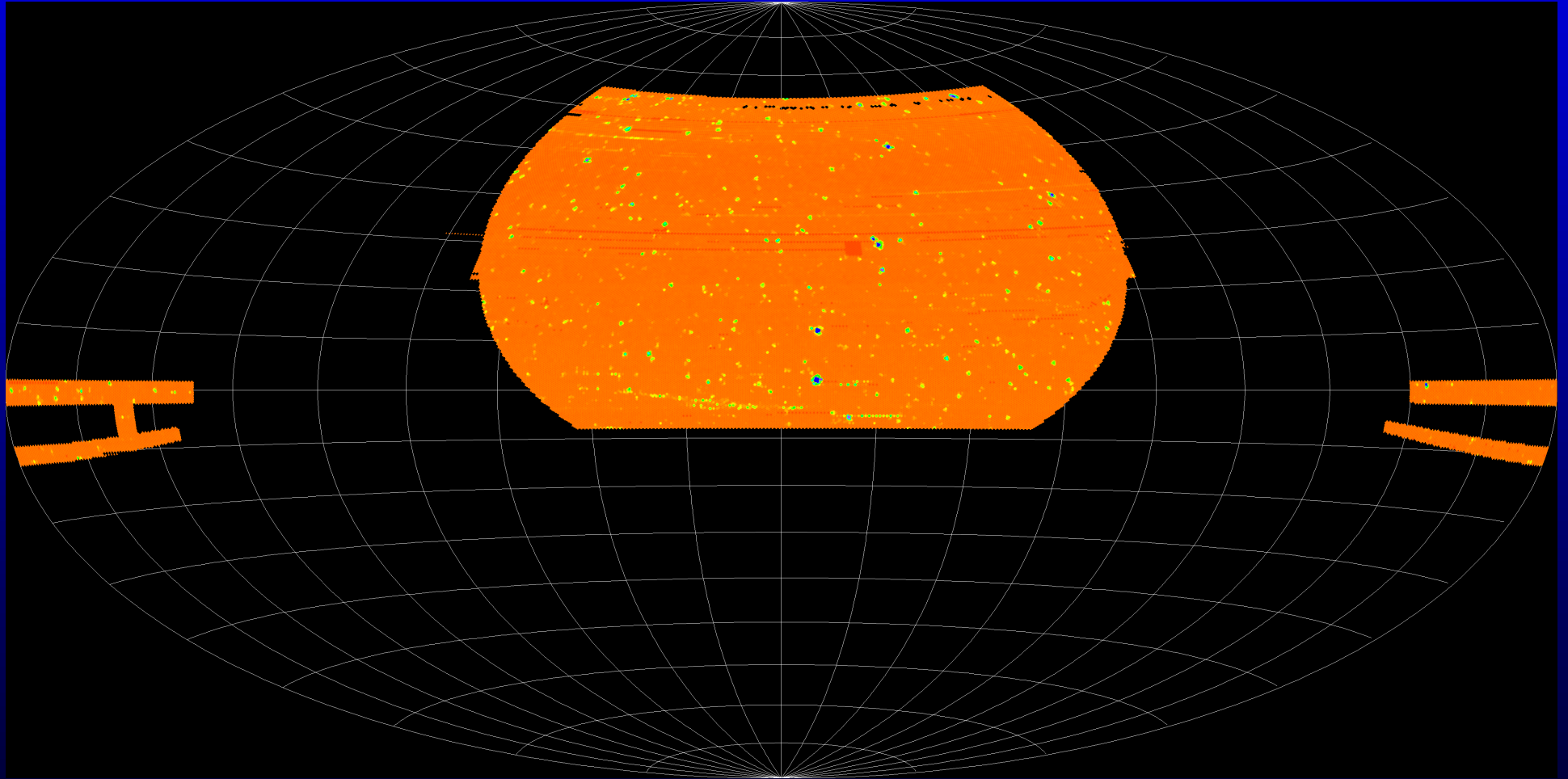
NVSS Over-Density – $|b| > 20$

FIRST



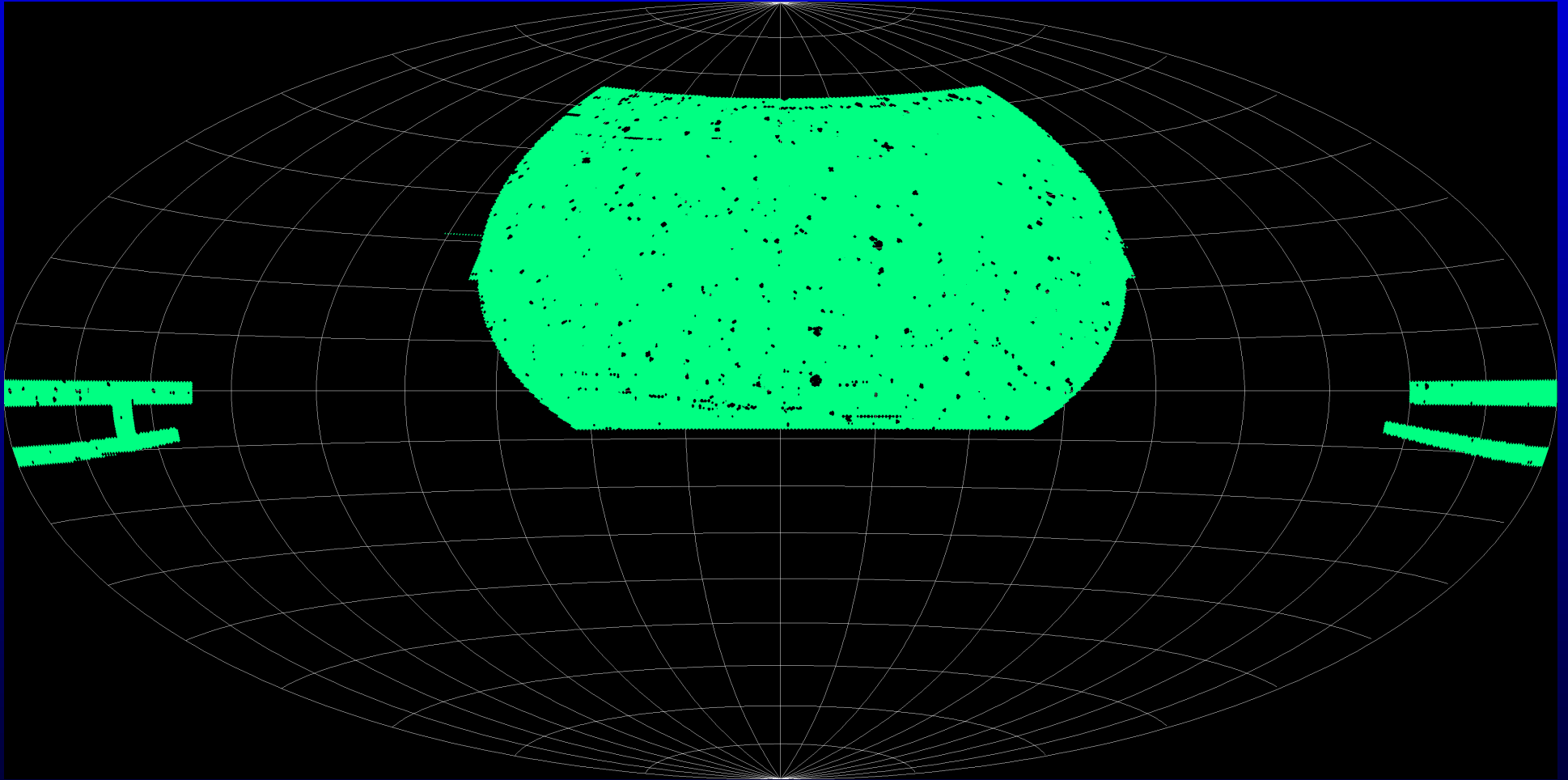
FIRST

FIRST



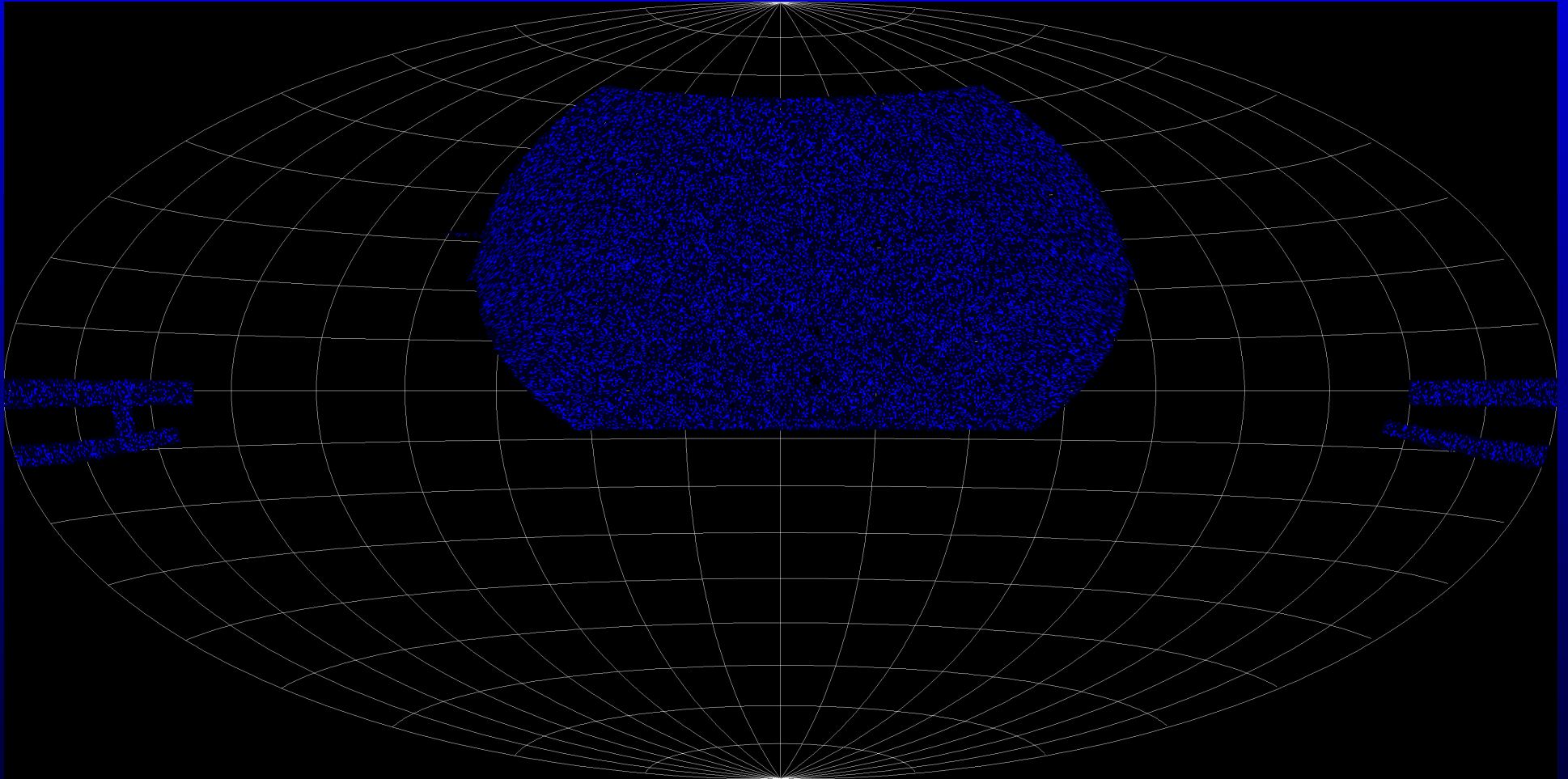
FIRST Background Flux

FIRST



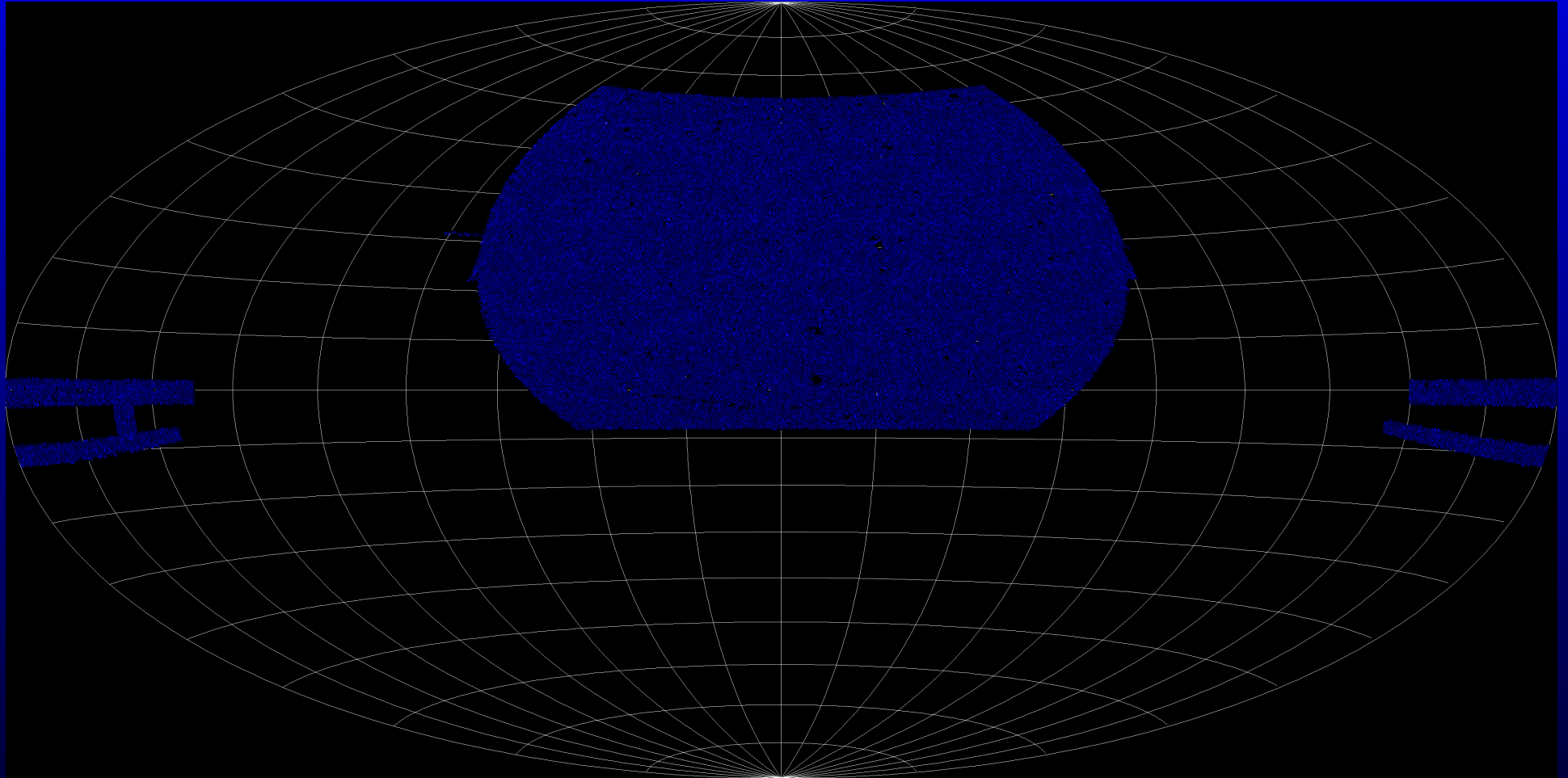
FIRST – background flux < 0.17 mJy

FIRST



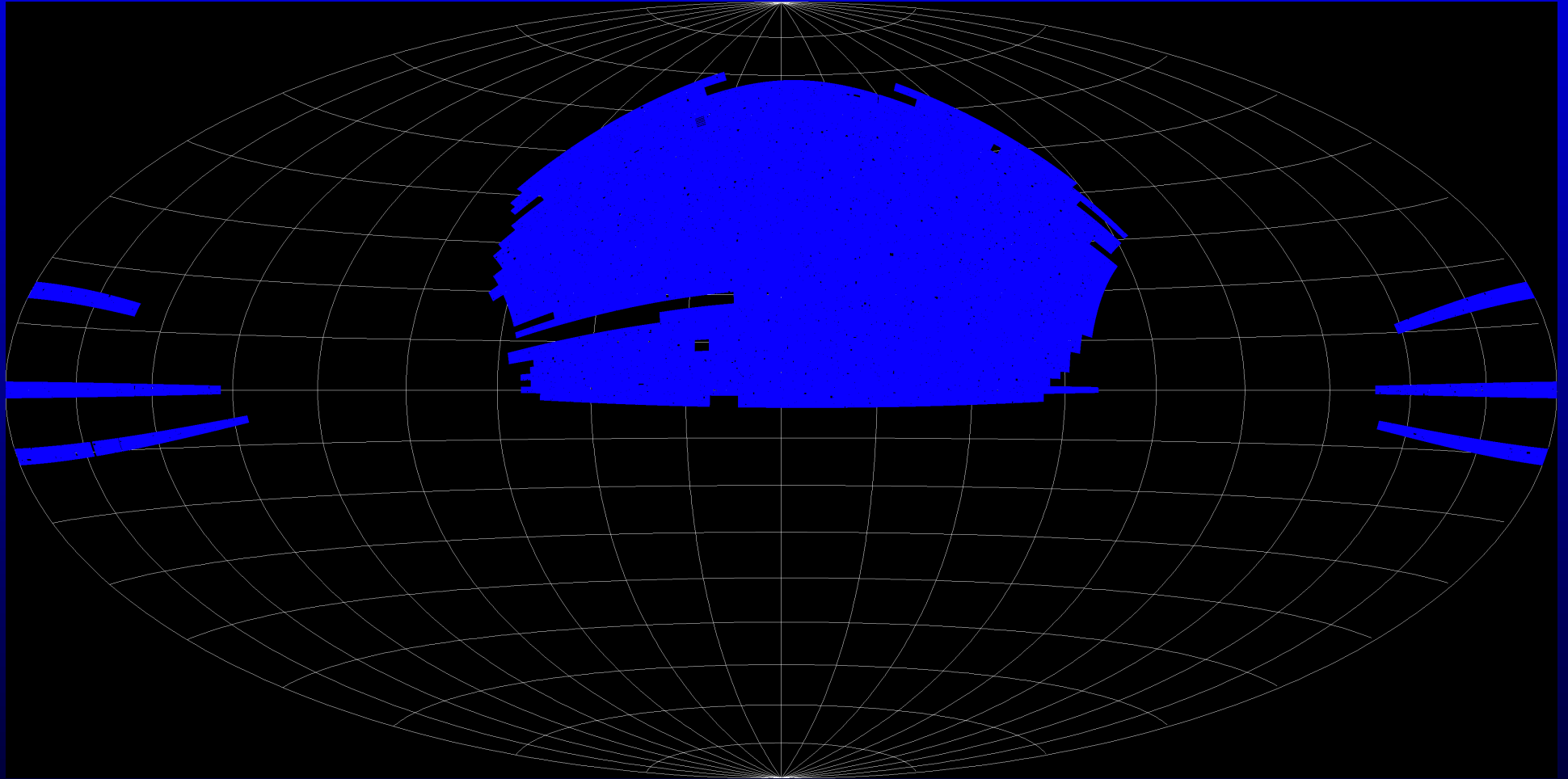
FIRST – flux > 50 mJy (AGNs with $z \sim 1.5$)

FIRST



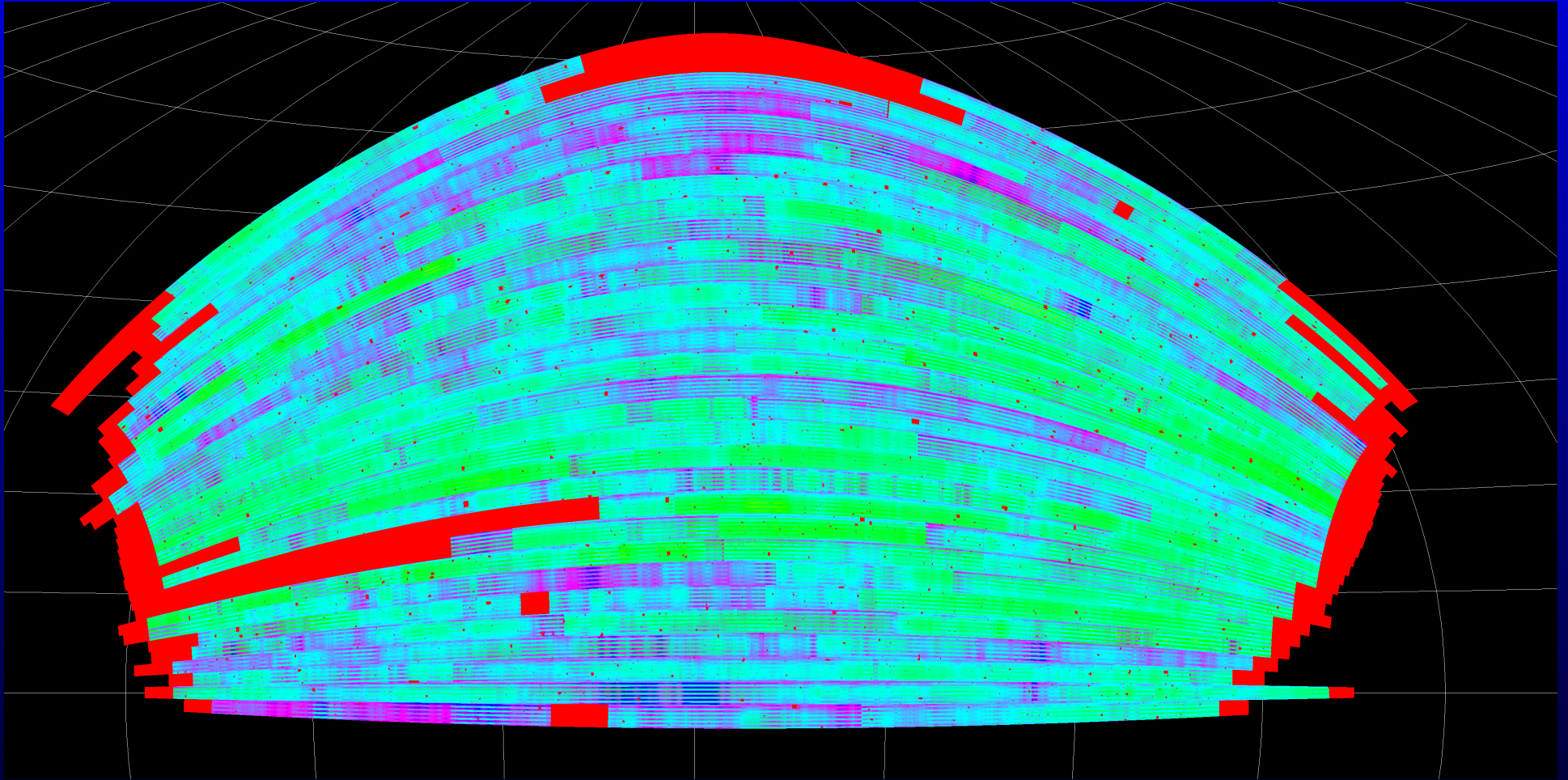
FIRST – flux < 10 mJy (star-forming galaxies with $z \sim 1$)

SDSS



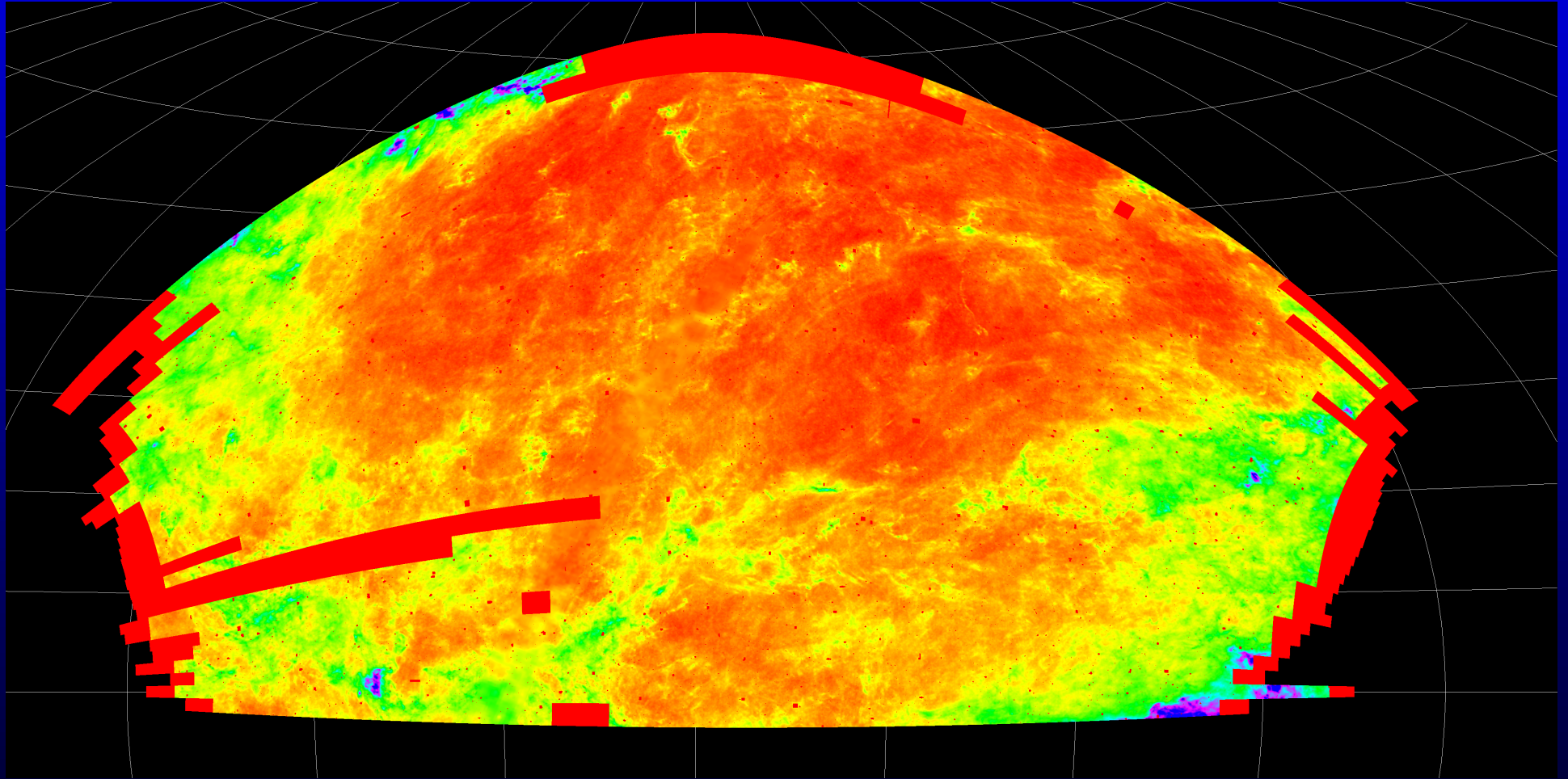
SDSS DR5 Photometric Survey

SDSS



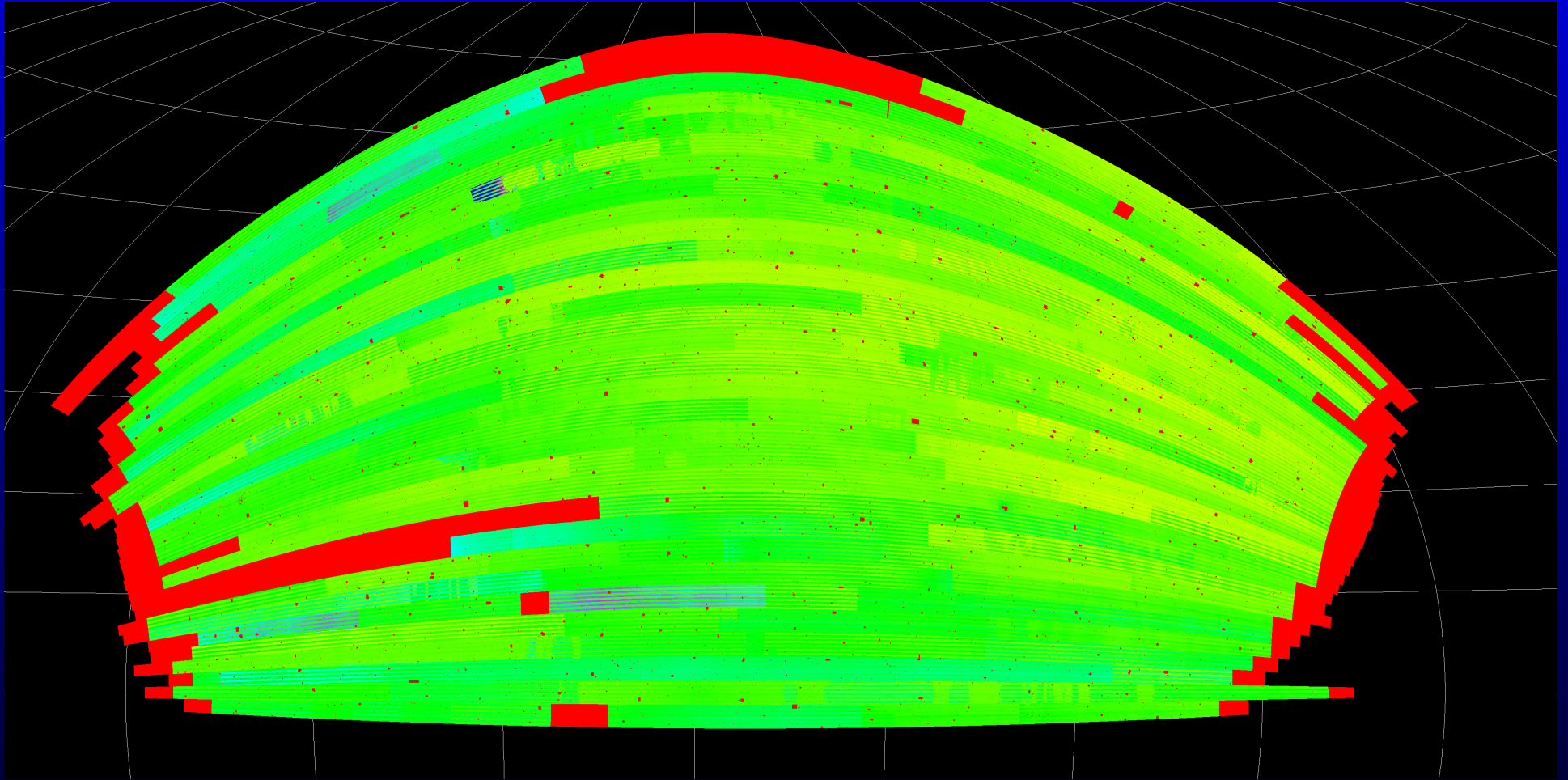
SDSS DR5 Photometric Survey – Seeing

SDSS



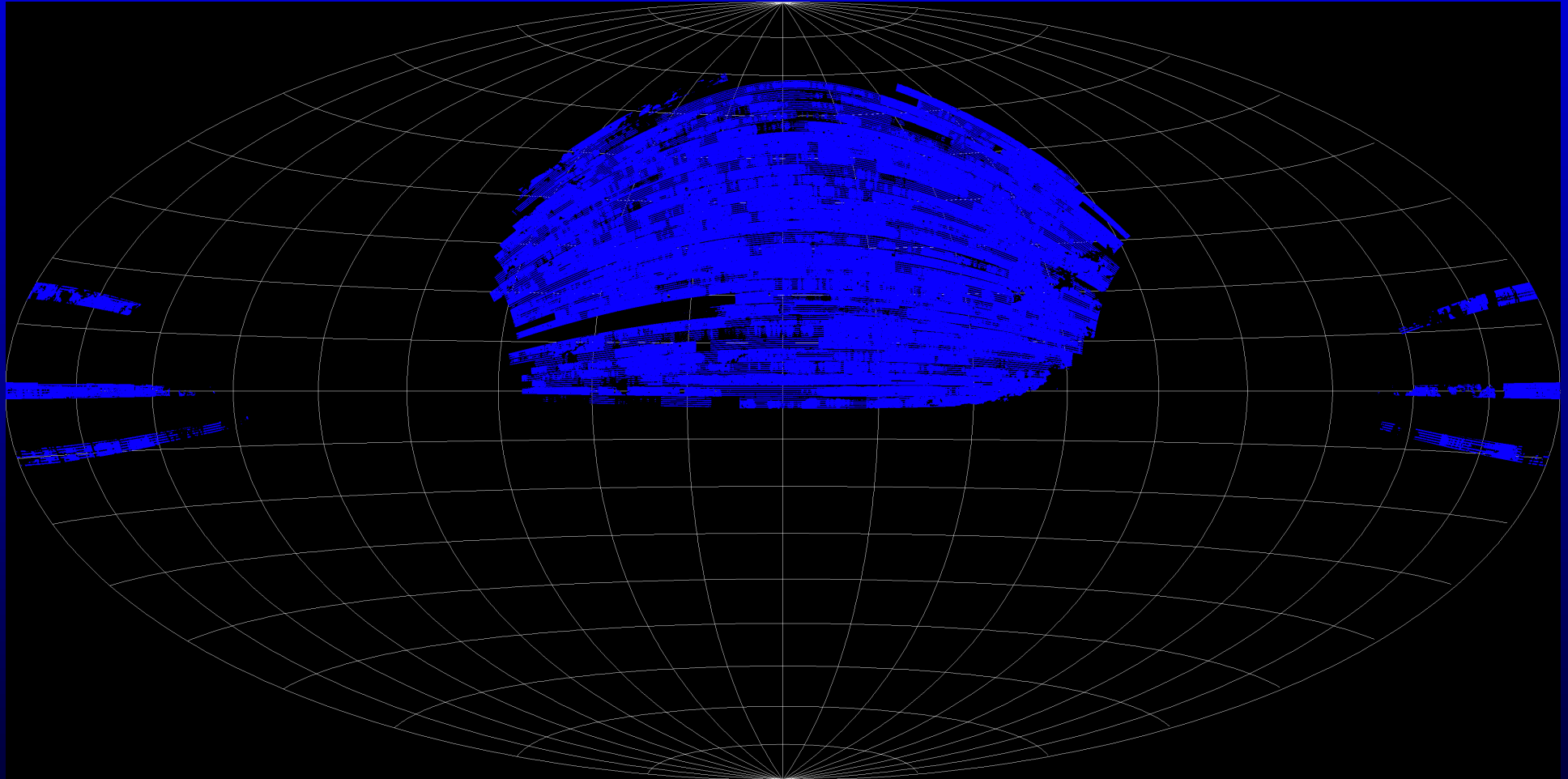
SDSS DR5 Photometric Survey – Reddening

SDSS



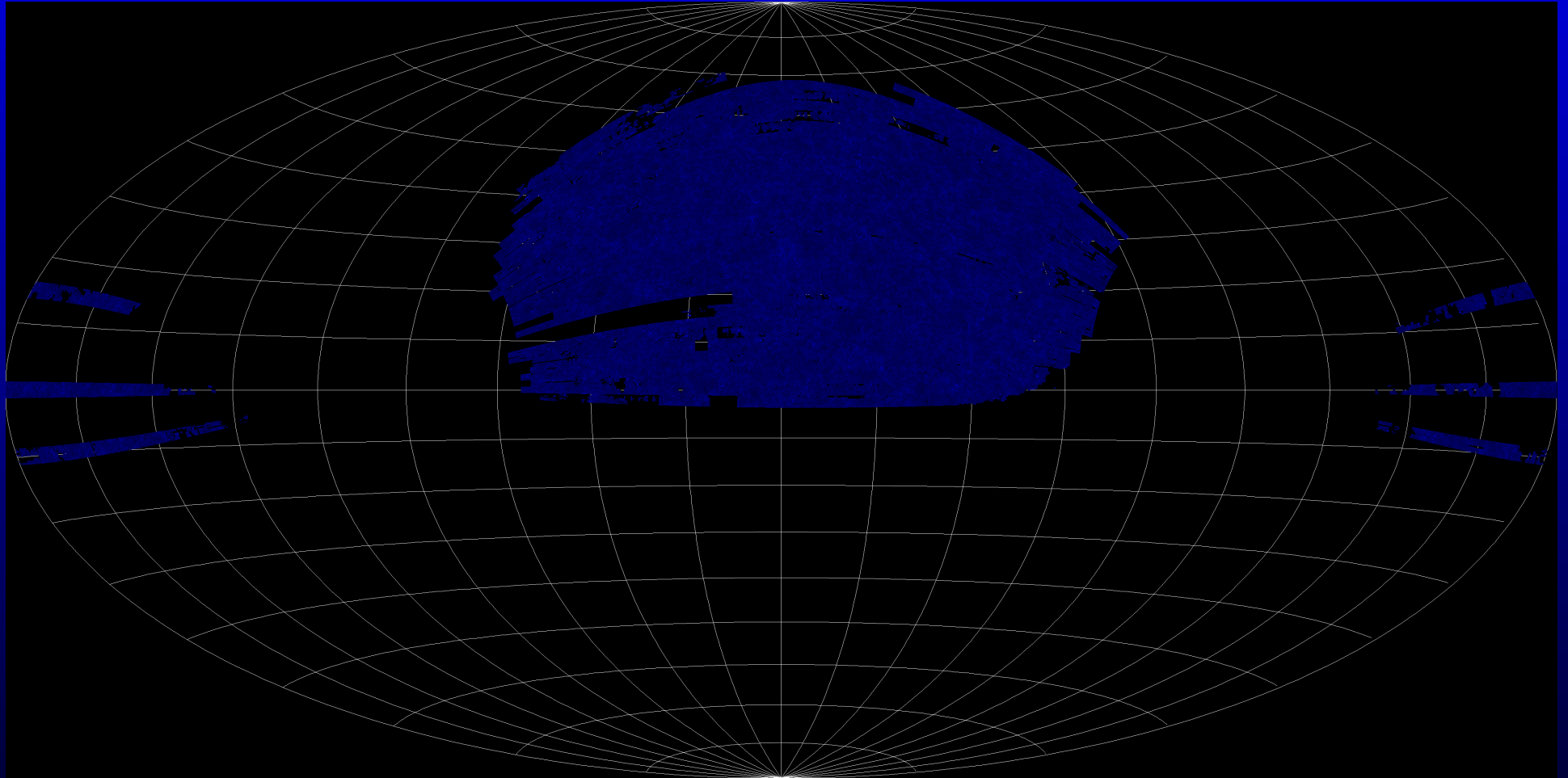
SDSS DR5 Photometric Survey – Sky Brightness

SDSS



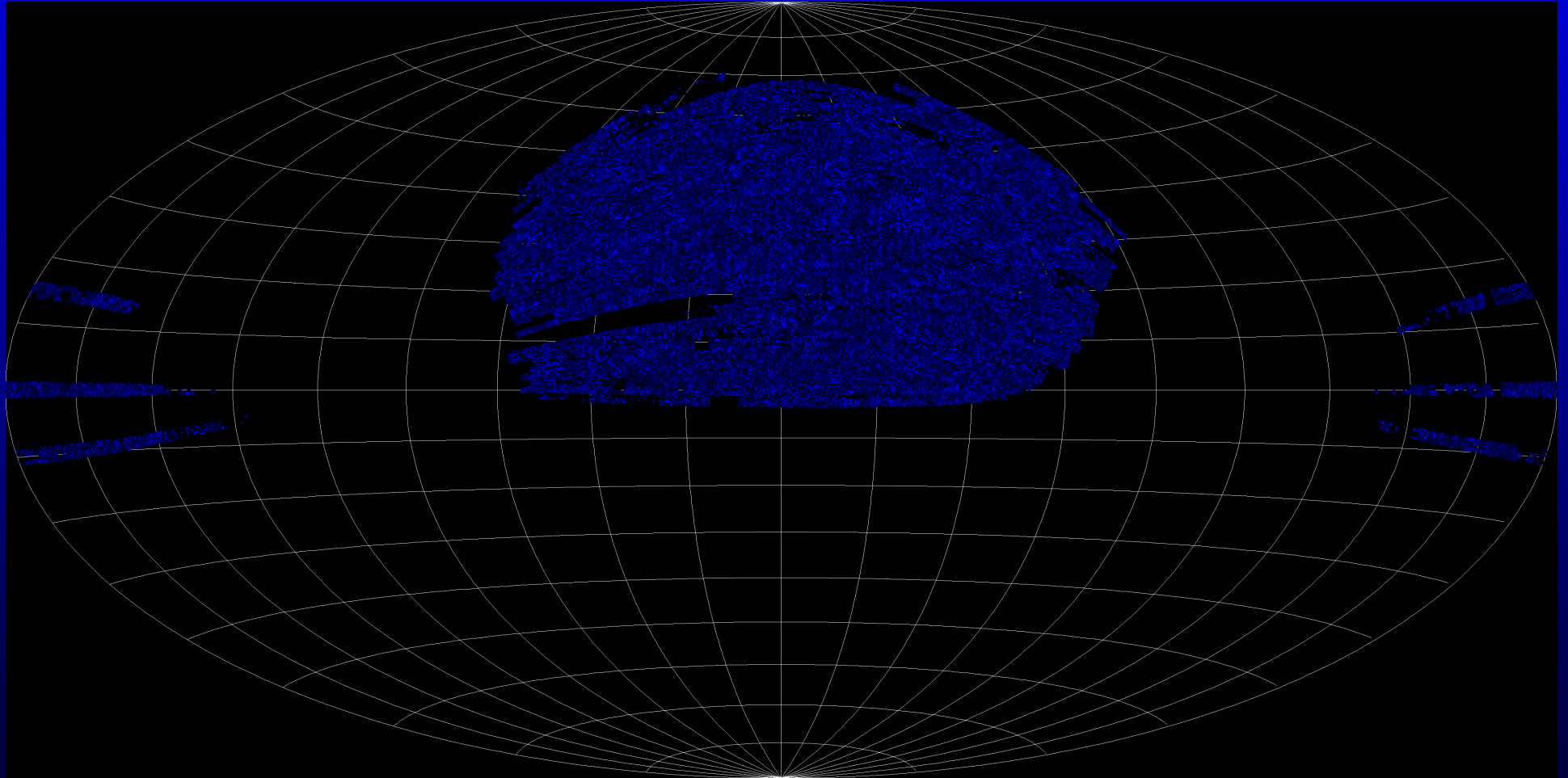
SDSS DR5 Photometric Survey – Masked against systematics

SDSS



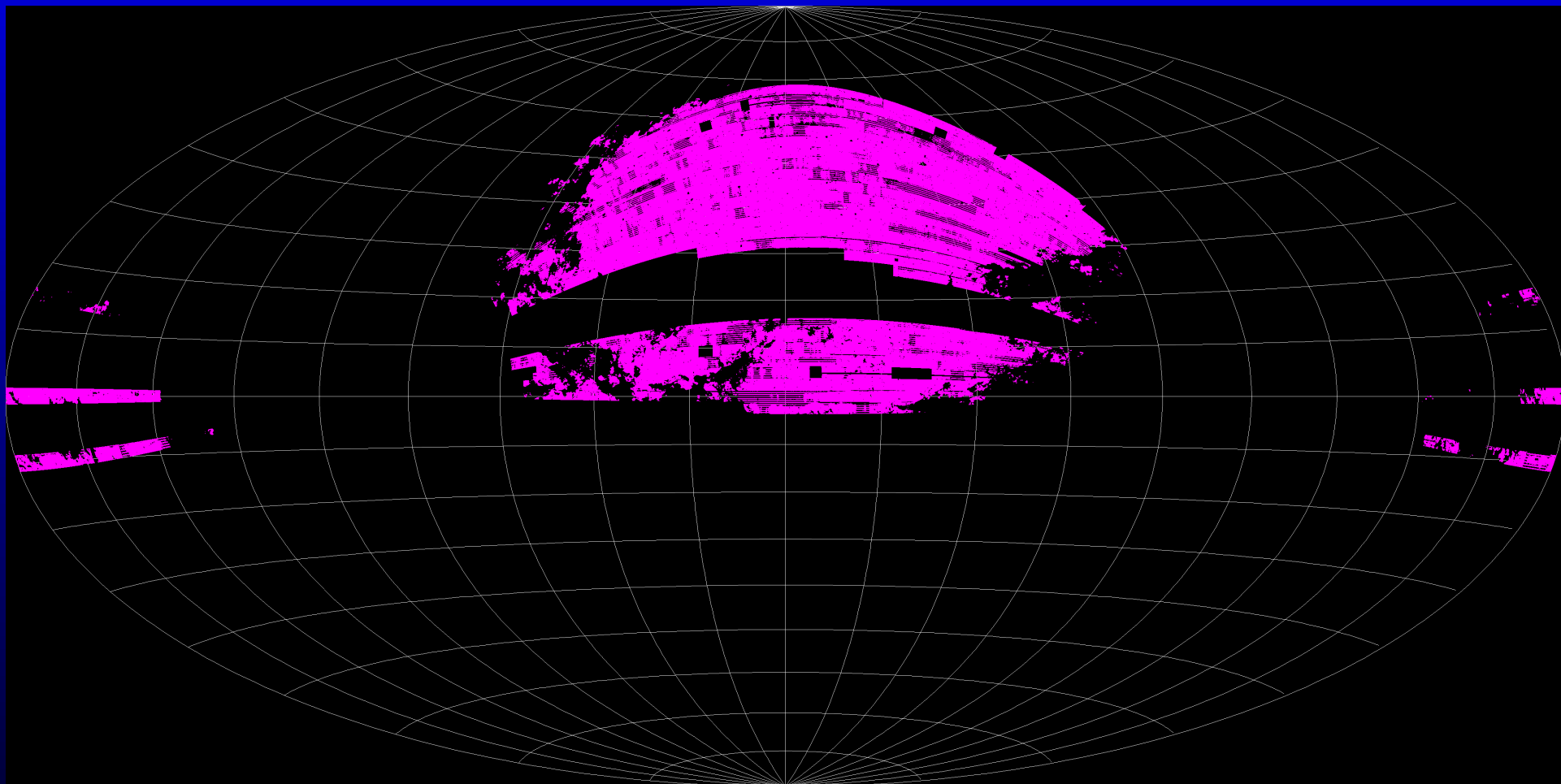
SDSS DR5 Magnitude-Limited ($20 < r < 21$, $z \sim 0.3$)

SDSS



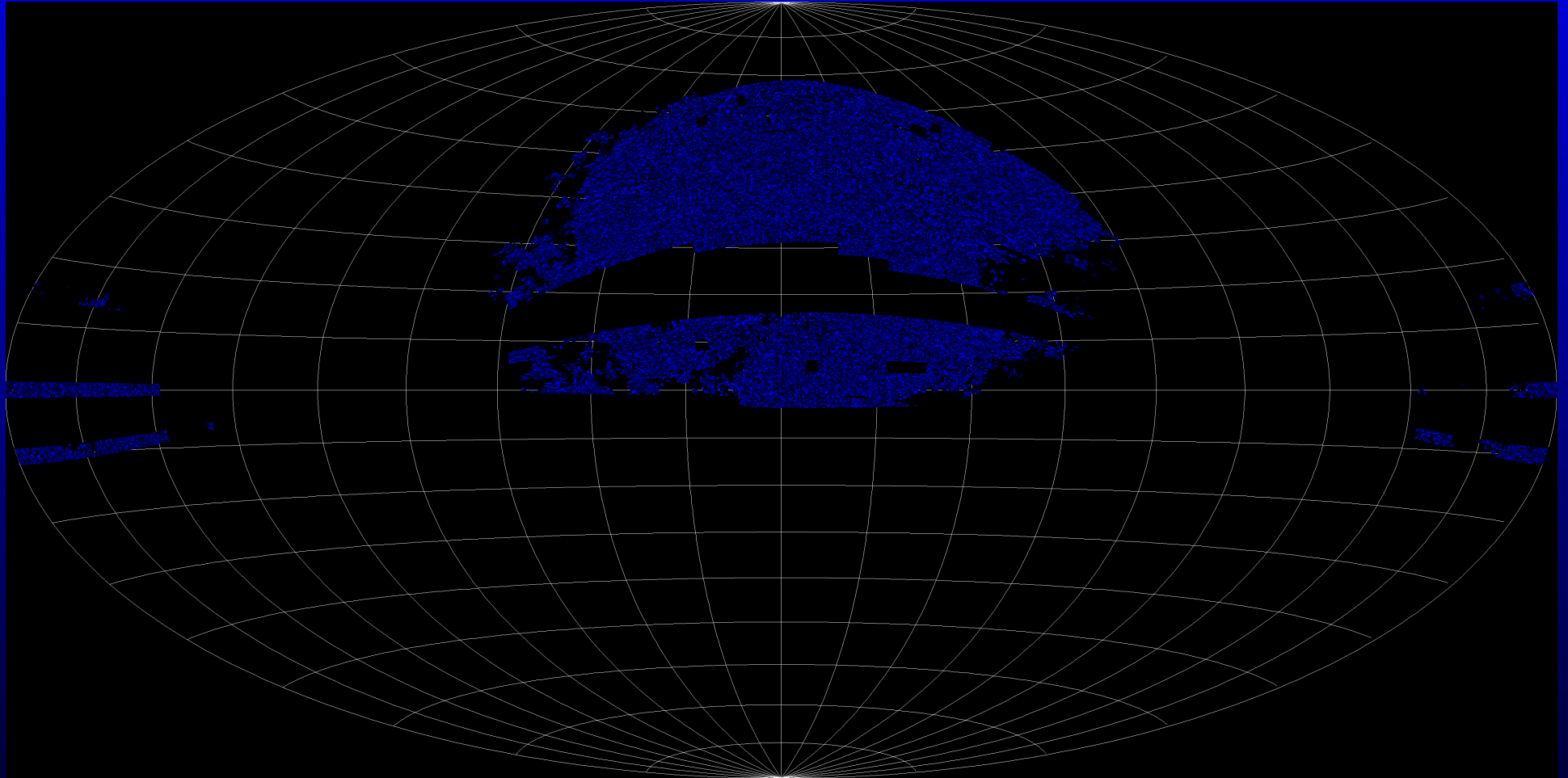
SDSS DR5 LRG ($z \sim 0.55$)

SDSS Photometric QSOs



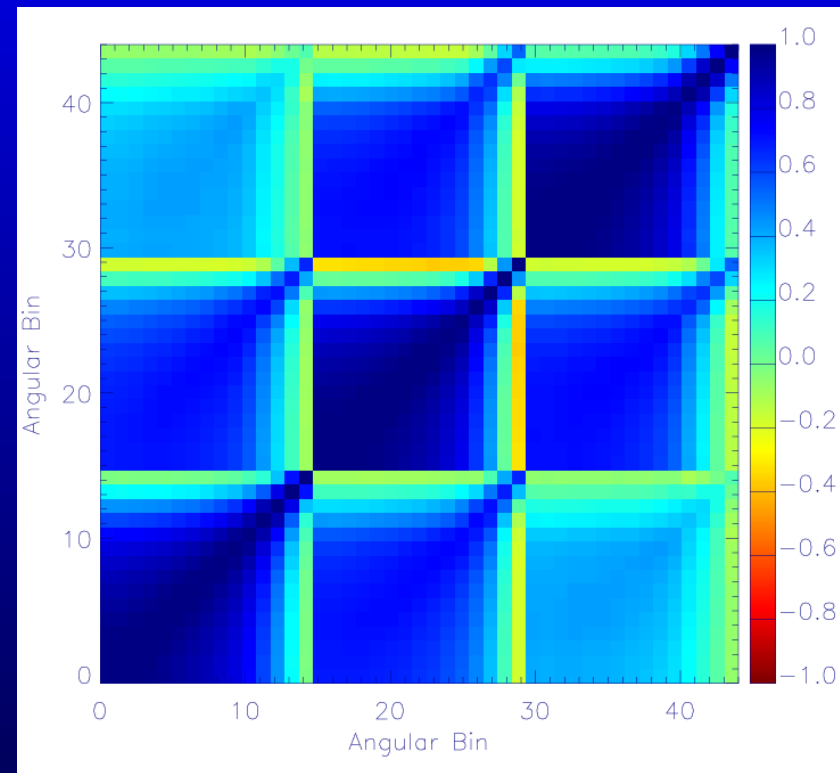
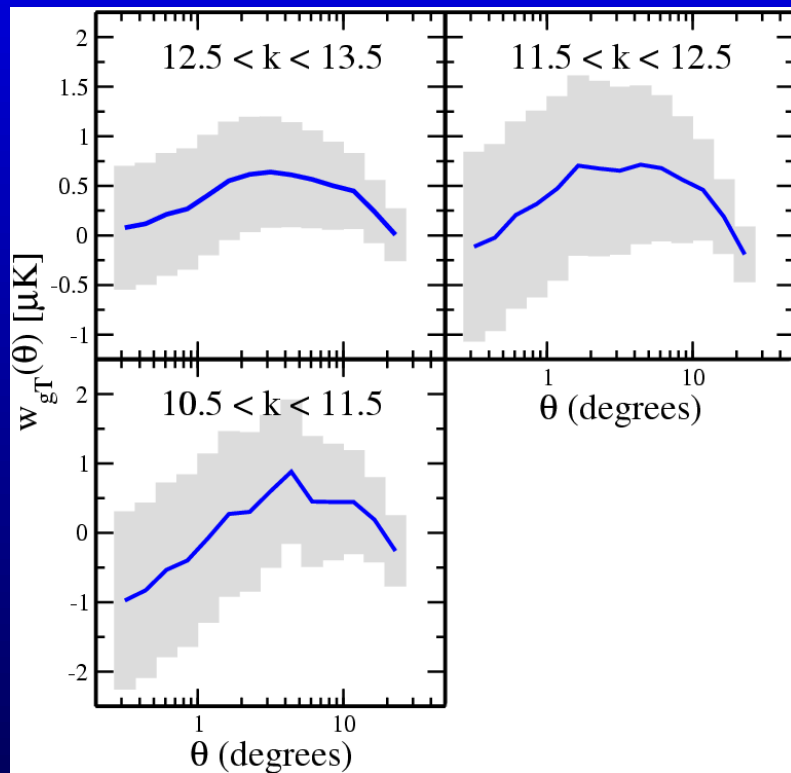
SDSS DR4 Photometric Survey – $A_g < 0.15$

SDSS



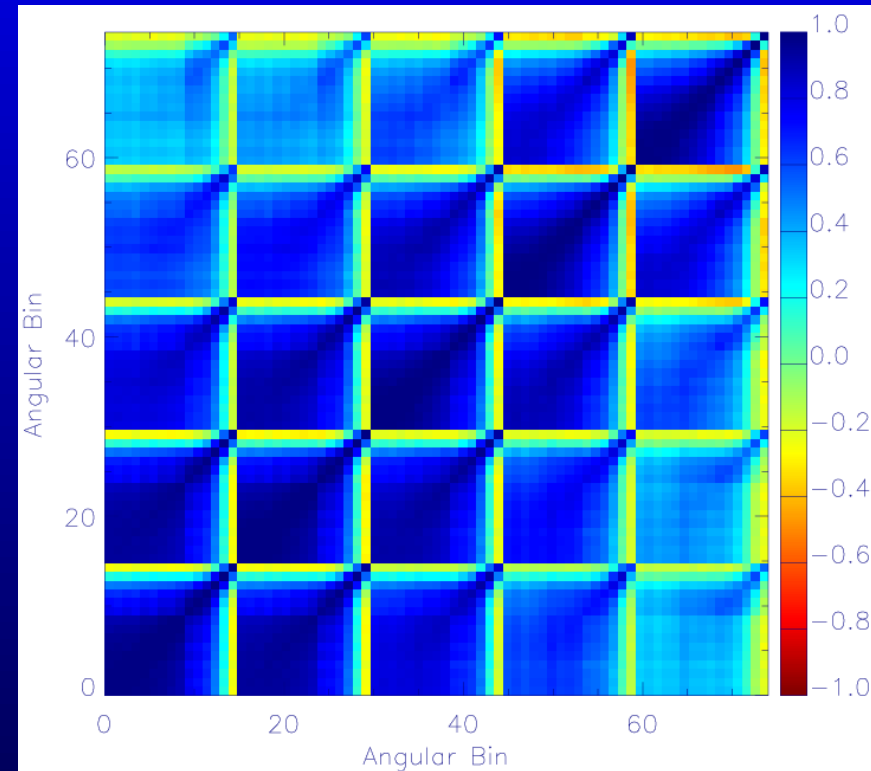
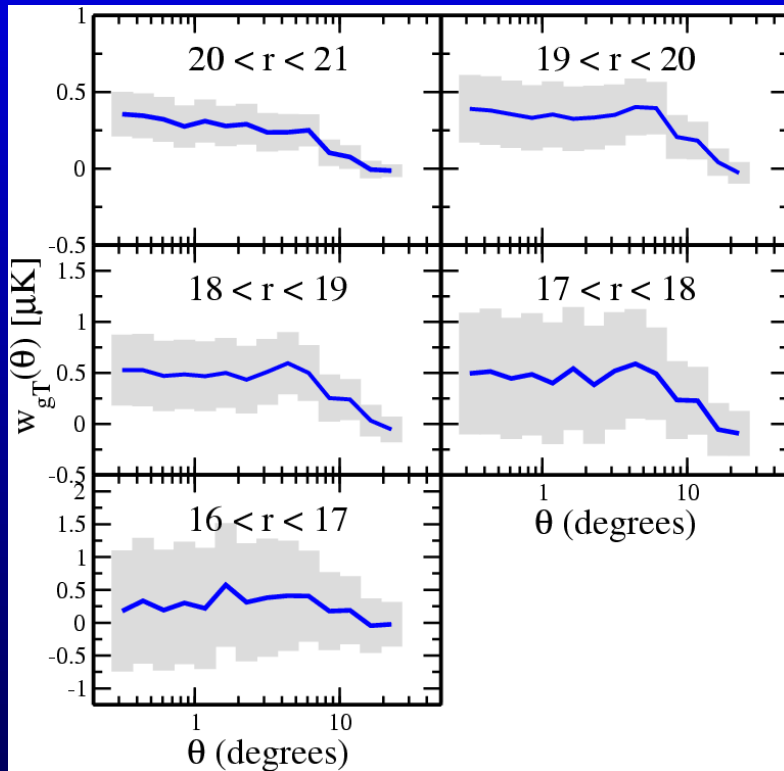
SDSS DR4 Photometric QSOs ($1 < z < 2.5$)

Results: 2MASS



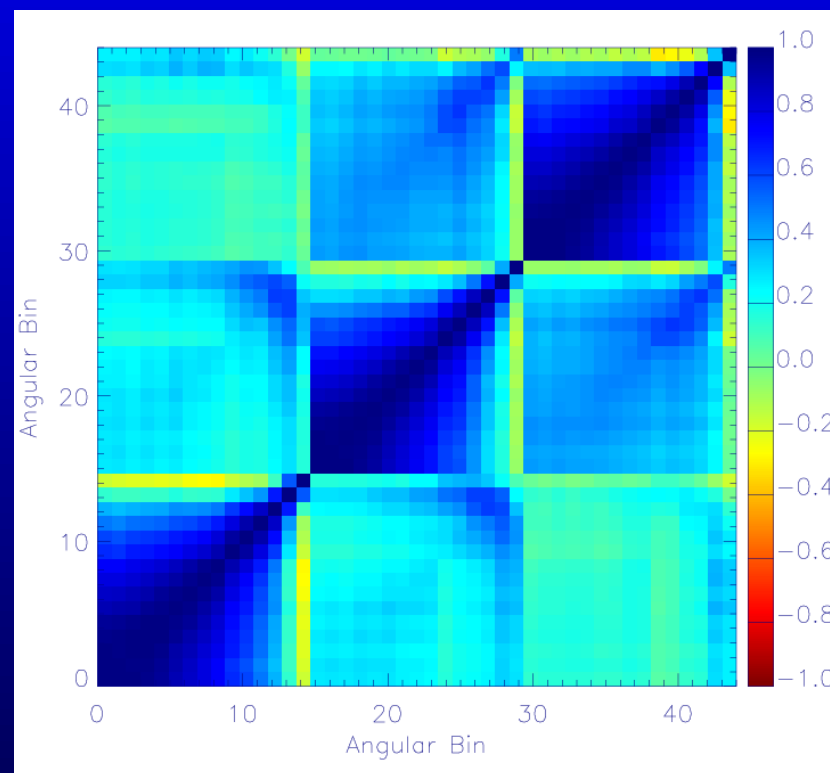
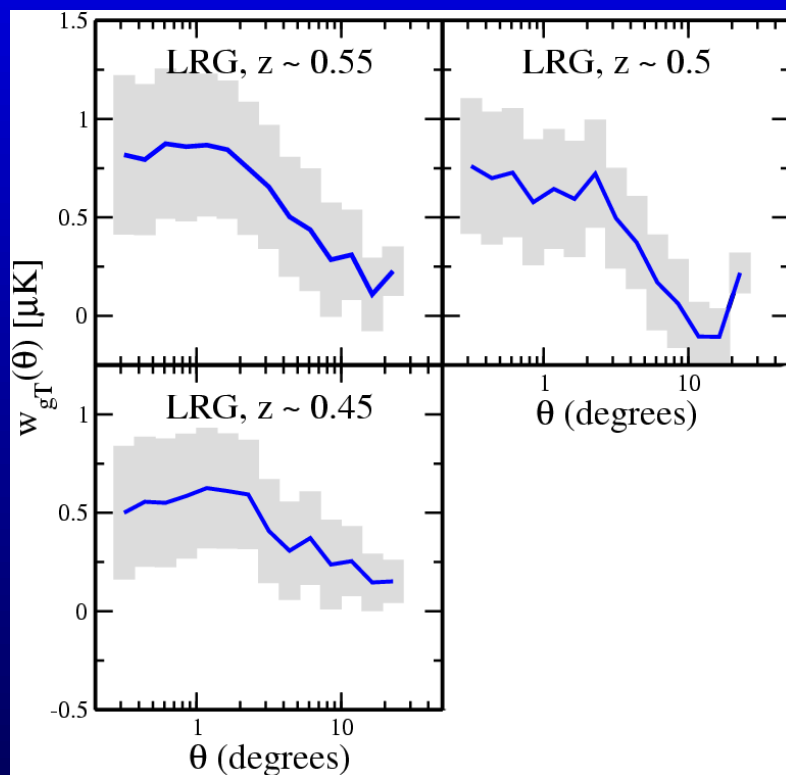
- Strong SZ signal at small angles; increasing as $z \rightarrow 0$
- $\chi^2 = 59.8$ for 45 angular bins: 1.3σ

Results: SDSS Magnitude Limited



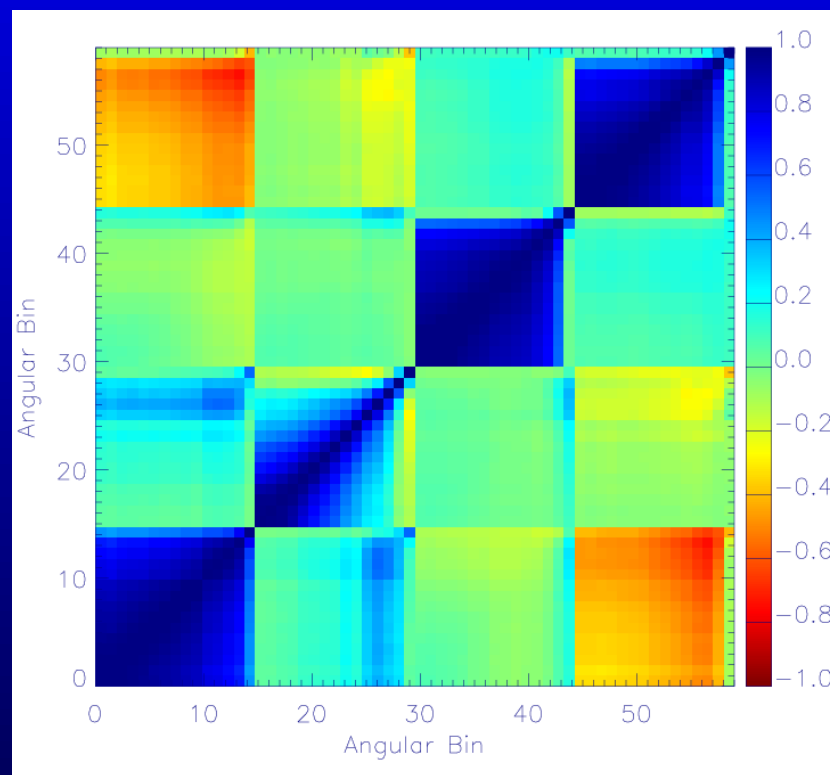
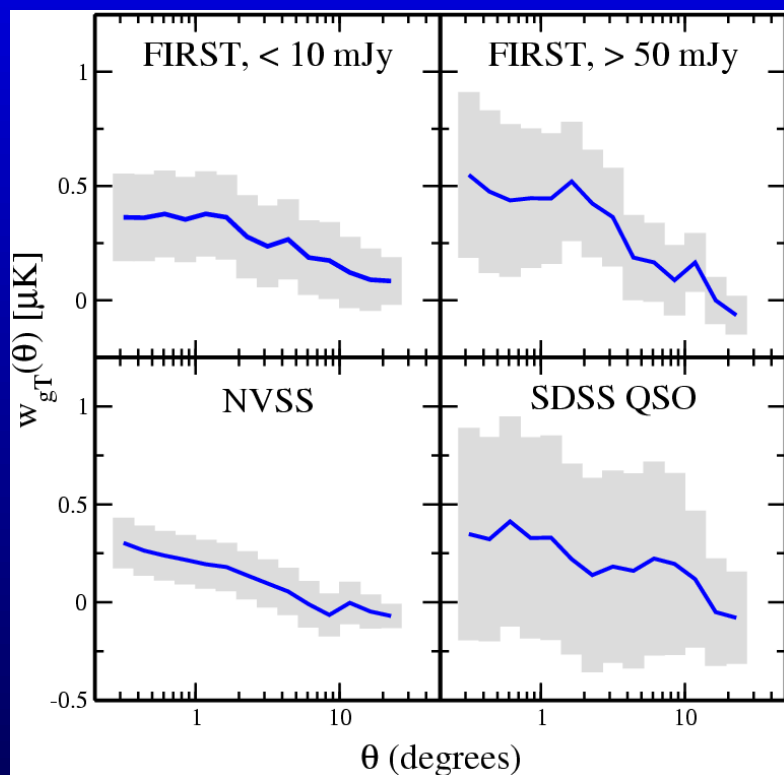
- Increasing S/N as z increases
- $\chi^2 = 136.4$ for 75 angular bins: 3.0σ

Results: SDSS LRGs



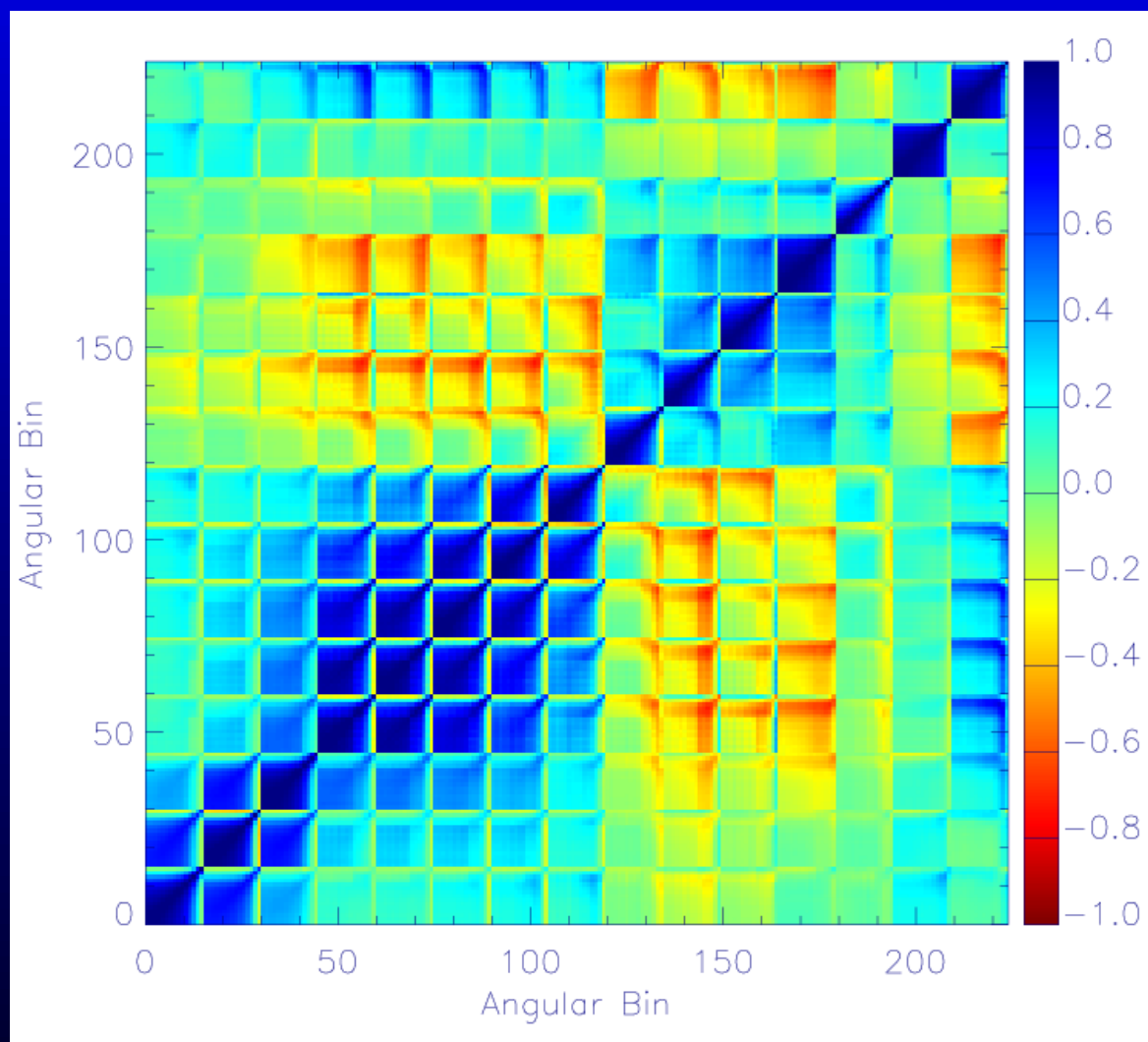
- Dropped lowest redshift bin from Scranton et al (2003); lower S/N
- $\chi^2 = 87.2$ for 45 angular bins: 2.7σ

Results: High Redshift

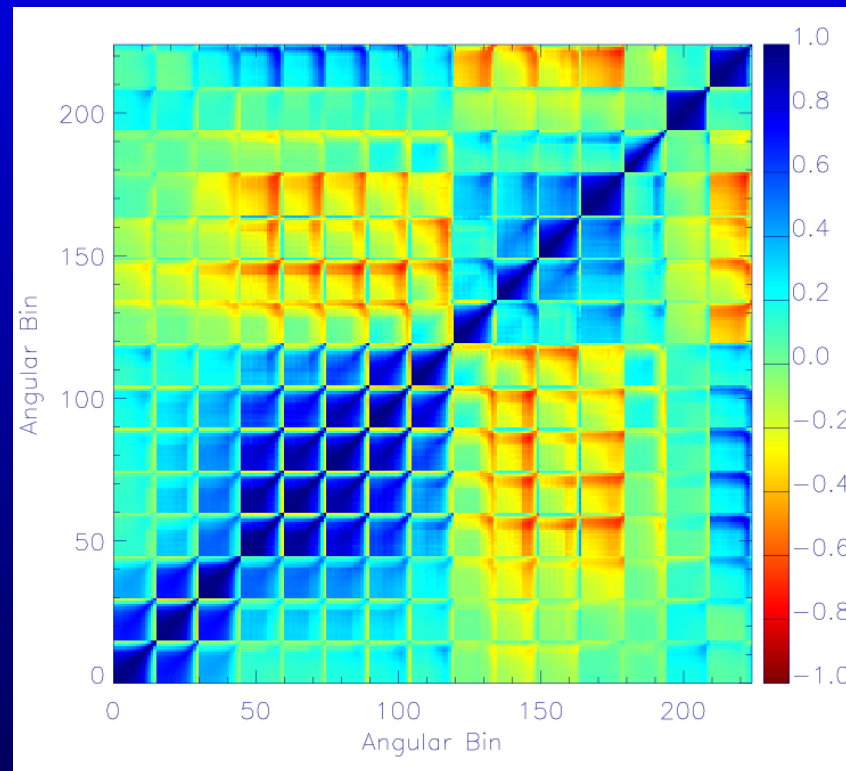


- Huge χ^2 for NVSS; probably contaminated.
- $\chi^2 = 130.7$ for 60 angular bins: 3.6σ

Results: Global Sample $0 < z < 2.5$



Results: Global Sample $0 < z < 2.5$

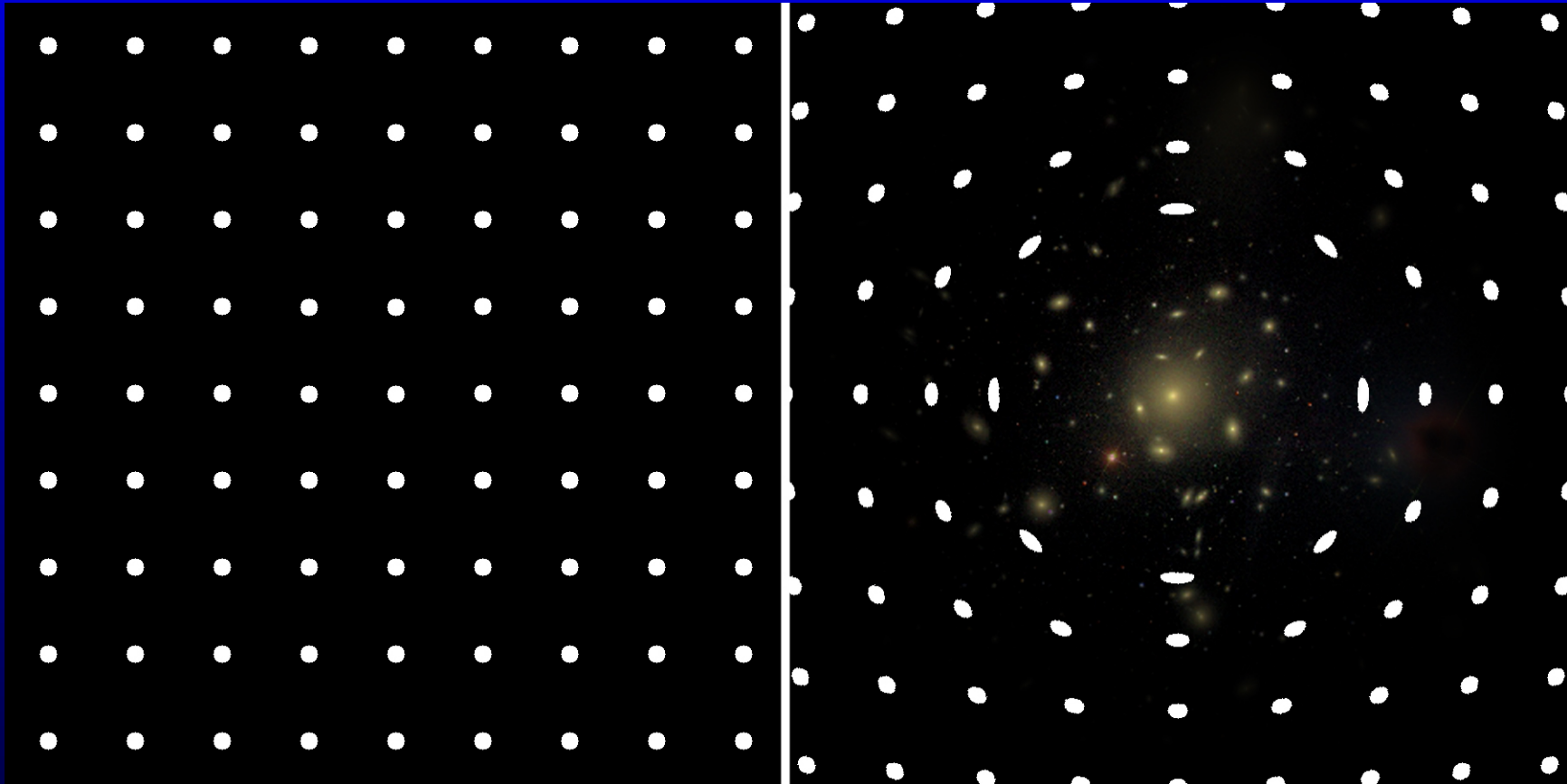


- Significant anti-correlations; magnification bias? Quite possibly (LoVerde, Hui & Gaztanaga, *in preparation*).
- $\chi^2 = 461.5$ for 225 angular bins: 6.2σ (5.3σ w/o NVSS)

Summary

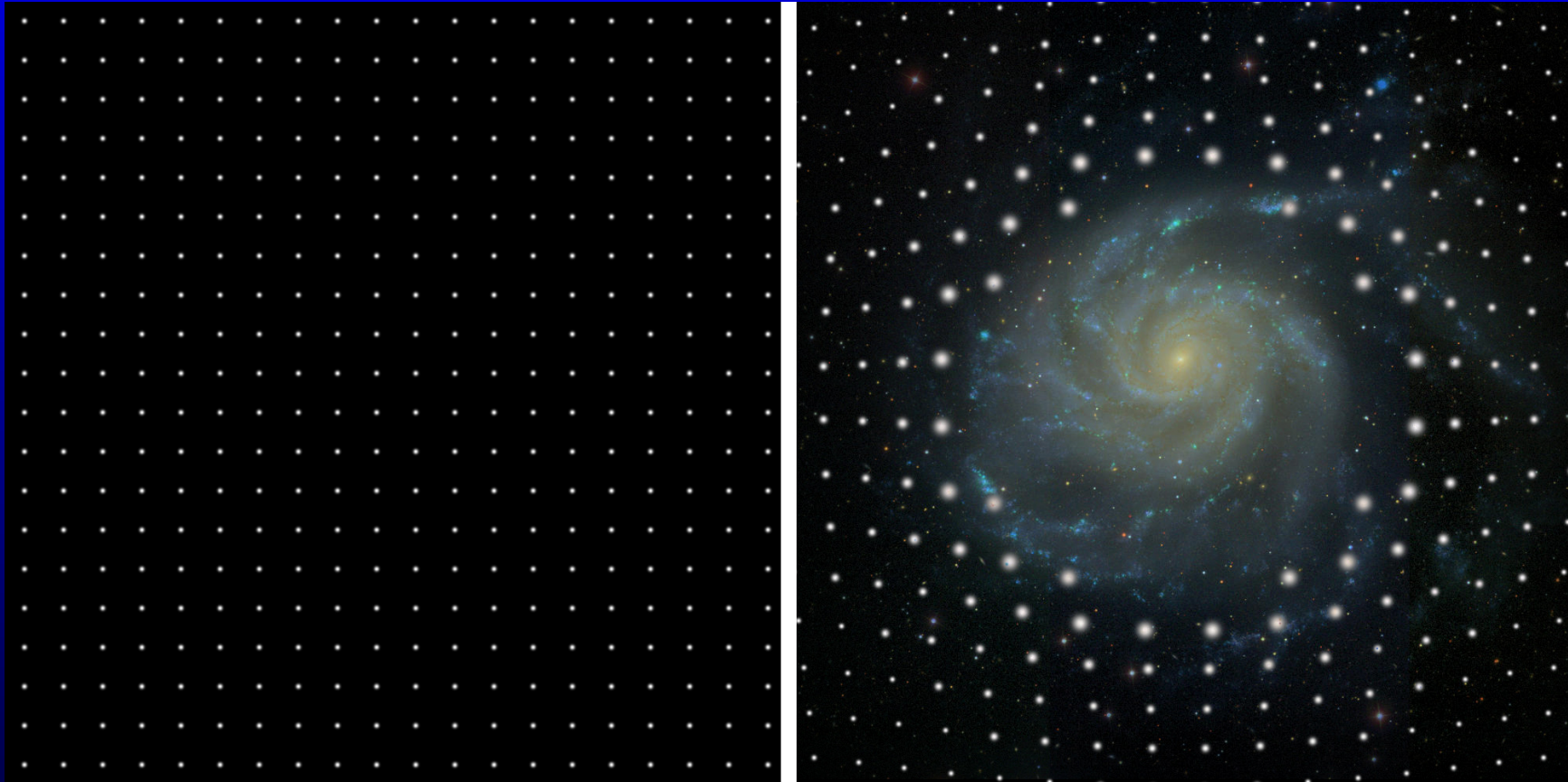
- Current set of surveys all demonstrate ISW signal to one degree or another, but the S/N of any given survey remains relatively small.
- Combining the detections from multiple surveys increases the overall S/N to roughly 5σ
- Part of this increase appears to be due magnification bias between samples at different redshifts. Depending on the sample, magnification can be a significant or even dominant part of the total signal at high z .
- While the tools and resources exist to do this measurement quickly and efficiently, one should probably budget more than 20 days next time.

Two Effects of Gravitational Lensing



- Weak lensing of background sources introduces **shear** and **magnification**

Two Effects of Gravitational Lensing



- Magnification (μ) increases flux (amplification); decreases density (dilution).

Quantifying Cosmic Magnification

- If we are in the weak lensing regime ($\mu \approx 1$),

$$\begin{aligned}
 w_{\text{GQ}}(\theta) &= 12\pi^2 \Omega_M (\alpha(m) - 1) \int d\chi \, dk \, k \, \mathcal{K}(k, \theta, \chi) P_{gm}(k, \chi) \\
 &= (\alpha(m) - 1) \times w_0(\theta),
 \end{aligned} \tag{1}$$

where $\alpha(m)$ is the power-law slope of the QSO number counts, \mathcal{K} depends on the foreground and background redshift distributions and $P_{gm}(k)$ is the galaxy-dark matter power spectrum.

- For $\alpha(m) > 1$, increasing amplification outweighs the dilution effect, yielding a positive cross-correlation. For $\alpha(m) < 1$, dilution wins and the cross-correlation is negative.

Magnification & ISW

- Standard ISW redshift kernel:

$$\mathcal{K}_{ISW} \sim \int d\chi W_G(\chi) \frac{\partial}{\partial \chi} \left[\frac{D(\chi)}{a(\chi)} \right] \quad (2)$$

where χ is the comoving distance, $W_G(\chi)$ is the redshift distribution of the galaxies and $D(\chi)$ is the linear growth factor. For Λ CDM, potential decay peaks at $z = 0$, so amplitude increases as $z \rightarrow 0$.

- Magnification (convergence) kernel:

$$\mathcal{K}_\kappa \sim (\alpha - 1) \int d\chi W_F(\chi) \frac{g_B(\chi)}{a} \quad (3)$$

where

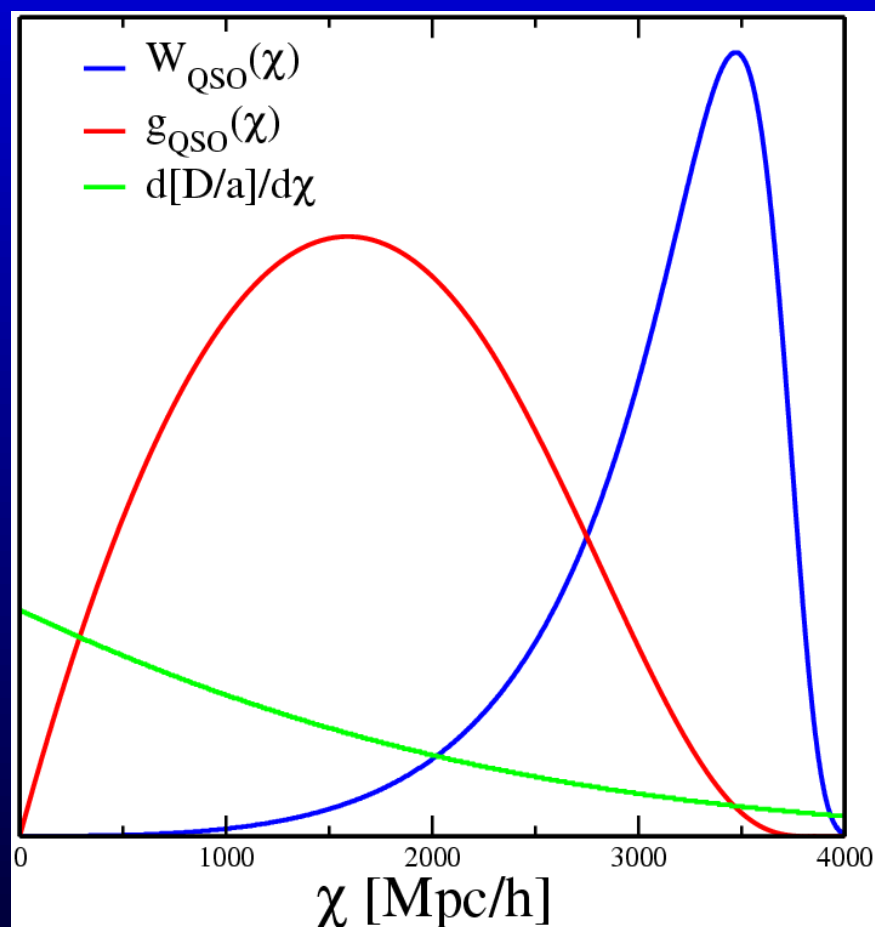
$$g_B(\chi) = \int d\chi' \frac{\chi(\chi' - \chi)}{\chi'} W_B(\chi') \quad (4)$$

- Magnification-ISW kernel:

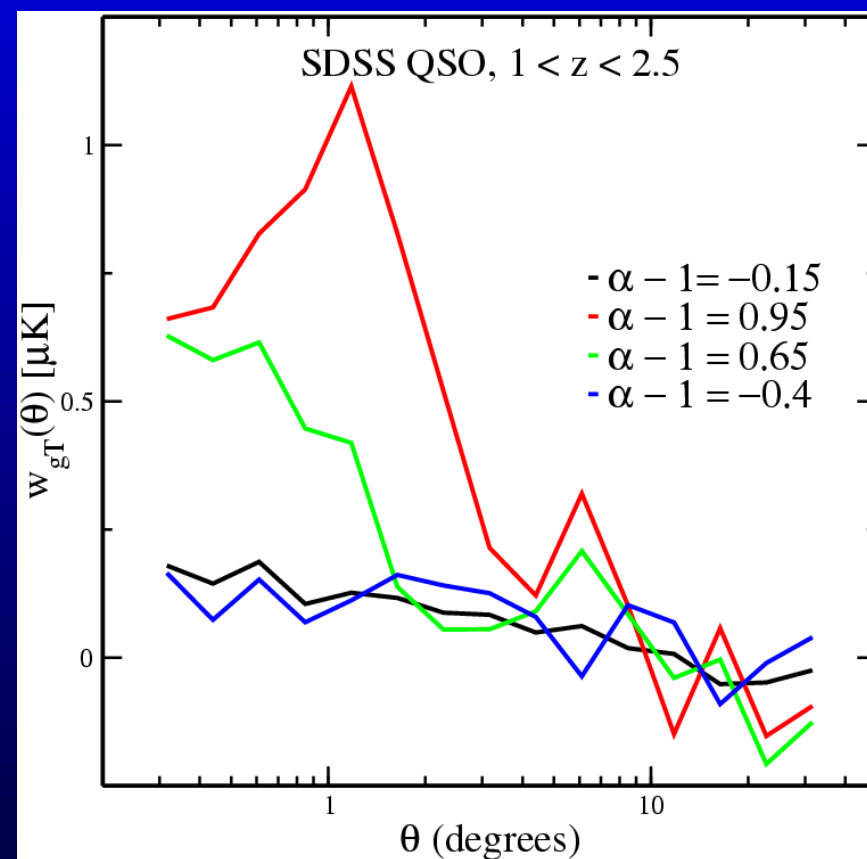
$$\mathcal{K}_{ISW,\kappa} \sim (\alpha - 1) \int d\chi \frac{g_G(\chi)}{a} \frac{\partial}{\partial \chi} \left[\frac{D(\chi)}{a(\chi)} \right] \quad (5)$$

- For $\alpha - 1 \neq 0$ and $z > 0.5$, the pure ISW effect falls off sharply as $\Omega_\Lambda \rightarrow 0$. Magnification is generated by foreground structure at lower redshift potentials where the decay is large, hence its contribution increases, relatively.
- For field galaxies $\alpha - 1 \approx 0$, so need to choose galaxy subsets like LRGs, QSO or radio galaxies (or use an optimal estimator (?)).

Graphic Magnification



Redshift Dependencies for QSOs



Preliminary Results with SDSS QSOs